BULLETIN

OF THE INSTITUTE OF PHYSICS AND THE PHYSICAL SOCIETY

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47 BELGRAVE SQUARE, LONDON, S.W.1. TELEPHONE: BELGRAVIA 6111

Supplement to the BULLETIN *of The Institute of Physics, June, 1961*

Physics Courses in Colleges of Technology 1961-62

This supplement contains announcements of physics courses and special lectures that will be available during the 1961-62 session in some of the principal Colleges of Technology. It is hoped that this will be of use to students, to young graduates wishing to know of postgraduate lectures and to all concerned with the training of assistants.

COLLEGE OF TECHNOLOGY, OXFORD

SCHOOL OF SCIENCE

Full-time courses for

The Graduateship Examinations of The Institute of Physics and The Royal Institute of Chemistry

University of London External General B.Sc.

General Certificate of Education at Advanced Level

Part-time day and evening courses for

The Ordinary and Higher National Certificate in Applied Physics, Chemistry, Metallurgy and the Endorsed Certificate in Biology

The Licentiateship and Associateship Examinations of The Institution of Metallurgists

The Graduateship Examinations of The Institute of Physics and The Royal Institute of Chemistry

Full particulars from The Principal, College of Technology, Headington Road, Oxford. Tel. No.: Oxford 63434

KINGSTON-UPON-HULL COLLEGE OF TECHNOLOGY

Principal:

EMLYN JONES,
M.Sc., F.R.I.C.

DEPARTMENT OF PHYSICS

A full-time Three-year course for the External B.Sc. General Degree of London University.

Part-time Short Courses in:

Radioisotope Techniques

Electronics

High Vacuum Technology

Microscopy

Non-destructive Testing

Prospectus and further details of courses from the Head of the Physics Department, College of Technology, Queen's Gardens, Kingston-upon-Hull.

THE POLYTECHNIC

309 Regent Street, W.1

DEPARTMENT OF MATHEMATICS AND PHYSICS

Full-time and part-time day courses are available for B.Sc. General in Pure Mathematics, Physics and Chemistry (Part I), Physics and Mathematics or Chemistry (Part II), B.Sc. Special in Physics and Grad. Inst.P.

Evening courses are offered in Statistics, Electronics, Postgraduate Mathematics and Physics.

Prospectuses may be obtained from the Director of Education.

NOTTINGHAM and DISTRICT TECHNICAL COLLEGE

BURTON STREET, NOTTINGHAM

Principal:

D. A. R. CLARK,
M.Sc.(Tech.), M.I.Mech.E.,
M.B.I.M., A.F.R.Ae.S.

Full time Course for B.Sc. (General)

London University (External)

A three-year full-time course for this degree is provided in Chemistry, Botany, Zoology, Physics and Mathematics.

Fees: *Under 18 - Nil.*
Over 18 - £21 per annum.

Application forms may be obtained from the

Principal, Nottingham and District Technical College, Burton Street, Nottingham.

NORTH STAFFORDSHIRE COLLEGE OF TECHNOLOGY

Principal:

E. R. PATRICK,
Ph.D., B.Eng.,
A.M.I.Mech.E., A.M.I.E.E.

Head of Department:

R. TEALE, M.A., A.Inst.P.

PHYSICS DEPARTMENT

SESSION 1961/62

Courses in Pure and Applied Physics

1. Graduateship of The Institute of Physics.
2. Ordinary and Higher National Certificate in Applied Physics.
3. Full and part-time courses for G.C.E.
4. Instrument Maintenance, City and Guilds of London Institute, Ordinary and Advanced Certificate.
5. Courses on various topics, e.g.
   - Temperature Measurement,
   - Electronics of Nuclear counting equipment,
   - Nuclear Physics,
   - Vacuum Physics,
   - Instrumentation and Automatic control;

   are run as demand arises.

Further details of courses or general information may be obtained from the Head of the Department.

ADVANCED ENGINEERING TRAINING

The College of Aeronautics

offers courses at post-graduate level in

AERONAUTICAL SCIENCE AND TECHNOLOGY
SPACE TECHNOLOGY · FLUID MECHANICS · GUIDED MISSILES
CONTROL ENGINEERING (Process Control and Flight Control)
THE PHYSICS AND MECHANICS OF STRUCTURAL MATERIALS
WELDING TECHNOLOGY · PRECISION ENGINEERING
PRODUCTION TECHNOLOGY AND INDUSTRIAL ADMINISTRATION
OPERATIONAL RESEARCH · ERGONOMICS

The Advanced School of Automobile Engineering

offers courses at post-graduate level in

AUTOMOBILE ENGINEERING

Candidates for admission should be university graduates in engineering, science or mathematics or have attained that standard of education through engineering training and experience. The successful completion of a course leads to the award of a Diploma.

Information on these courses, and on bursaries which are available, can be obtained from

The Warden, The College of Aeronautics, Cranfield, Bletchley, Bucks

Sunderland Education Authority

SUNDERLAND TECHNICAL COLLEGE

SESSION 1961-62

COURSES IN PURE AND APPLIED PHYSICS

1. **Diploma in Technology—Applied Physics**
   A four-year "Sandwich" course in Applied Physics for the Diploma in Technology is in operation. The course will provide a balanced training for the industrial physicist and give exemption from the academic requirements of the Institute of Physics for Graduateship and corporate membership.

2. **B.Sc. Pure Science**
   A three-year full-time course for the external B.Sc. General Degree of London University is offered in the subjects of Physics, Chemistry and Mathematics.

3. **Higher National Certificate in Applied Physics**
   Part-time day and evening courses are provided for the Higher National Certificate in Applied Physics.

4. **Short Courses**
   (*a*) Particle Size Analysis by J. H. Harris, B.Sc., A.Inst.P., commencing Thursday, October 5, 1961.
   (*b*) Heat Transfer by J. C. Williams, B.Sc., A.Inst.P., commencing Wednesday, January 31, 1962.

Further details of these courses may be obtained from the Registrar, Technical College, Sunderland.

BOROUGH POLYTECHNIC

BOROUGH ROAD, S.E.1

The following undergraduate courses in Physics are available:—

Sandwich Course (four years)
leading to the
DIPLOMA IN TECHNOLOGY IN APPLIED PHYSICS
(with specialization in Applied Nuclear Physics)

Part-time (Day or Evening) Courses
leading to the
GRADUATESHIP OF THE INSTITUTE OF PHYSICS

Part-time (Day or Evening) Courses
in preparation for
SCIENCE DEGREES
(External)
of the University of London

Special Postgraduate Courses in Applied Physics

SESSION 1961/62

Lecture Courses, by specialist lecturers, will be held weekly in the following subjects:—

Nuclear Power
Nucleonic Circuitry (Electronic Equipment used in Nuclear Physics)
Nuclear Particle Techniques (Nuclear Instruments and isotope applications)
Reactor Instrumentation and Control
Digital Circuit Techniques
Principles and Applications of Transistors
Principles of Pulse Techniques.

Laboratory Courses (Part-time or Full-time) will also be held in the following subjects:—

Transistors
Nuclear Power Technology
Pulse Circuits and Techniques
Nucleonic Techniques and Measurements
Design, Use and Maintenance of Electronic Equipment used in Nuclear Physics

Prospectuses of Sandwich or of Part-time courses and leaflets giving full particulars of postgraduate courses can be obtained from the Secretary, Borough Polytechnic, Borough Road, London, S.E.1.

CHELSEA COLLEGE OF SCIENCE AND TECHNOLOGY

DEPARTMENT OF PHYSICS

Head of Department: W. H. GEORGE, M.Sc., Ph.D., F.Inst.P.

INTERNAL DEGREE COURSES OF THE UNIVERSITY OF LONDON

B.Sc., M.Sc., Ph.d.

POSTGRADUATE COURSES, full- and part-time, beginning on October 2, 1961.

1. SOLID STATE PHYSICS
2. SEMICONDUCTORS
3. PHYSICAL ELECTRONICS
4. NUCLEAR PHYSICS
5. ACOUSTICS AND VIBRATION PHYSICS
6. OPTICS

Suitably qualified students may register as M.Sc. Internal students of the University of London.

B.Sc. INTERNAL DEGREE COURSES, full-time and "Sandwich", beginning on September 25, 1961

1. B.Sc. SPECIAL PHYSICS, full-time and "Sandwich".
2. B.Sc. GENERAL (Revised Regulations), full-time and part-time.

For students engaged in industry, the *sandwich* course is planned as an alternative part-time course in which students attend for two terms full-time and one term part-time in each of four sessions.

Prospectus, further details, and application forms may be obtained from:
The Secretary, Physics Dept., Chelsea College of Science and Technology, London, S.W.3. FLAxman 5747.

LEICESTER COLLEGE OF TECHNOLOGY AND COMMERCE

Principal: R. E. WOOD, M.Sc., F.Inst.P.

The following courses are amongst those to be offered during session 1961/62:—

SCHOOL OF CHEMISTRY

Postgraduate Diploma in Radiochemistry (four-term full-time course accepted by the Department of Scientific and Industrial Research and suitable for the tenure of its Advanced Course Studentships).

DEPARTMENT OF MATHEMATICS

Industrial Mathematics Including Data Processing (two-year full-time course with minimum entry qualifications of G.C.E. pass at Advanced Level in Mathematics).

SCHOOL OF PHYSICS AND APPLIED SCIENCE

Graduateship Examination of The Institute of Physics.

O.N.C. and H.N.C. in Applied Physics.

Electronic and Control Technology.

Short courses in Microwave Techniques, Transistors and Colorimetry.

Particulars of above courses may be obtained from the appropriate Head of Department.

Details of all other courses may be obtained on application to the Registrar, Leicester College of Technology and Commerce, Leicester. Tel. No. 50181.

CROYDON TECHNICAL COLLEGE

Principal:
D. A. GREEN,
M.B.E., B.Sc., M.Ed.

DEPARTMENT OF SCIENCE

Part-time day and evening courses are offered for the following qualifications:-

B.Sc. (General) - New Regulations

Graduateship of The Institute of Physics

Higher National Cert. in Applied Physics

Ordinary National Cert. in Applied Physics

Postgraduate evening courses on specialized Physics topics

Further particulars and information may be obtained from the Head of the Science Department, Croydon Technical College, Fairfield, Croydon.

BOURNEMOUTH MUNICIPAL COLLEGE OF TECHNOLOGY AND COMMERCE

Part-time day and evening courses are offered for the following qualifications:—

ORDINARY NATIONAL CERTIFICATE IN APPLIED PHYSICS

HIGHER NATIONAL CERTIFICATES IN APPLIED PHYSICS
(General Applied Physics or Reactor Technology)

GRADUATESHIP OF THE INSTITUTE OF PHYSICS

Full-time courses are also available for:—

B.Sc. (GENERAL)

Full details may be obtained from the Head of the Science Department, Dr. C. J. Cooper, B.Sc., A.R.C.S., F.R.I.C., Bournemouth Municipal College of Technology and Commerce, Lansdowne, Bournemouth.

CUMBERLAND EDUCATION COMMITTEE

WHITEHAVEN COLLEGE OF FURTHER EDUCATION

Part-time day and evening courses:—

ORDINARY NATIONAL CERTIFICATE IN APPLIED PHYSICS

HIGHER NATIONAL CERTIFICATE IN APPLIED PHYSICS

GRADUATESHIP OF THE INSTITUTE OF PHYSICS AND THE PHYSICAL SOCIETY

ALSO

FULL-TIME INTRODUCTORY COURSES IN NUCLEAR ENGINEERING

6 weeks duration

3 courses per year

Further details of these and other courses at the College may be obtained from the Principal, Whitehaven College of Further Education, Flatt Walks, Whitehaven

MIDDLESEX
COUNTY COUNCIL
Education Committee

BRUNEL COLLEGE OF TECHNOLOGY

WOODLANDS AVENUE
ACTON, W.3

DEPARTMENT OF MATHEMATICS

SPECIAL EVENING COURSES 1961-62

The following lectures have been arranged:

AUTOCODE FOR MERCURY DIGITAL COMPUTER

NUMERICAL ANALYSIS FOR AUTOMATIC COMPUTERS BASED ON CHEBYSHEV POLYNOMIALS

INTRODUCTION TO MATHEMATICAL PLANNING

NUMERICAL METHODS

PROGRAMMING THE NATIONAL ELLIOTT 803

VECTOR ANALYSIS

DIFFERENTIAL EQUATIONS

SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS BY NUMERICAL METHODS

MATHEMATICS FOR MECHANICAL ENGINEERS

MATHEMATICS FOR ELECTRONIC ENGINEERS

INTERMEDIATE STATISTICS

FINAL STATISTICS

QUEUEING THEORY AND APPLICATIONS

INFORMATION THEORY

Full particulars may be obtained from the Head of the Mathematics Department.

MIDDLESEX COUNTY COUNCIL

EDUCATION COMMITTEE

BRUNEL COLLEGE OF TECHNOLOGY

WOODLANDS AVENUE, ACTON, W.3

Principal: J. TOPPING, M.Sc., Ph.D., D.I.C., F.Inst.P.

The following courses are among those to be held during the session 1961-62. Autumn term begins September 21, 1961.

DEPARTMENT OF PHYSICS

Head of Department: C. A. HOGARTH, B.Sc., Ph.D., F.Inst.P.

DIPLOMA IN TECHNOLOGY IN APPLIED PHYSICS

A four-year Sandwich course commencing in January, 1962. Specialist subjects in the course include Nuclear Technology, X-ray Crystallography, Electronics, High Vacuum Technology, Electrical and Magnetic Properties of Solids, Applied Acoustics.

B.Sc. (GENERAL) DEGREE OF THE UNIVERSITY OF LONDON

The next part-time course begins in September and extends over four years.

HIGHER NATIONAL CERTIFICATE IN APPLIED PHYSICS

Subjects include Electronics, High Vacuum Technology, Applied Acoustics. New course begins in September, 1961, and is held on a day-release basis.

GRADUATESHIP OF THE INSTITUTE OF PHYSICS

A day-release course for holders of the Higher National Certificate in Applied Physics commencing September, 1961, and extending over two years.

Evening courses to postgraduate standard are offered in the following subjects: Non-destructive Testing, X-ray Crystallography, High Vacuum Technology, Ultrasonics, Health Physics, Industrial Radiology.

DEPARTMENT OF MATHEMATICS

Head of Department: J. CRANK, M.Sc., D.Sc., F.Inst.P.

DIPLOMA IN TECHNOLOGY IN MATHEMATICS

A four-year Sandwich course commencing in September, 1961. Modern Applied Mathematics, practical computation and Statistics are supported by relevant section of Pure Mathematics, Physics and Electronics. The course is open to employees of firms willing to support them, and also to school leavers. Local Education Authorities' Awards may be held by students attending this course.

Full details of courses and enrolment forms obtainable from the Academic Registrar.

(ACOrn 6661)

College of Advanced Technology

GOSTA GREEN, BIRMINGHAM, 4

Telephone: ASTon Cross 3611

Principal: P. F. R. VENABLES, Ph.D., B.Sc., F.R.I.C.

DEPARTMENT OF PHYSICS

Acting Head of Department: H. ORWIN, M.Sc.

SESSION 1961-62

FULL-TIME COURSES	B.Sc. General Degree (London External) B.Sc. Special Degree (London External) Diploma in Technology Sandwich Course in Applied Physics Ophthalmic Optics Nuclear Power Technology (Nine weeks course)
PART-TIME DAYS AND EVENING COURSES	Higher National Certificate in Applied Physics Graduateship of The Institute of Physics (Part II) B.Sc. General (London External) B.Sc. Special (London External) Associateship of the College
EVENING COURSES	Postgraduate Courses in:— Semiconductors, Transistors, Electronics, Vacuum Technique, Acoustics and Noise Measurement, X-rays and Ophthalmic Optics.
RESEARCH	Courses in Research are also available.

SESSION OPENS ON OCTOBER 2, 1961

Residential accommodation comprising single and double study bedrooms, with excellent communal facilities, available for male students at the College Hall of Residence.

Further particulars and forms of application for the full-time courses and details of other courses are given in the prospectus and may be obtained from the Bursar.

WELSH COLLEGE OF ADVANCED TECHNOLOGY

DEPARTMENT OF APPLIED PHYSICS

Head of Department: J. R. BRISTOW, B.Sc., Ph.D., F.Inst.P., A.M.I.Mech.E.

DIPLOMA IN TECHNOLOGY IN APPLIED PHYSICS

A four-year Full-time Course (i.e. three years in College and one year in industry) leading to the above Diploma, is open to both College and industry based students. The next session commences on September 27, 1961.

This Diploma will be a qualification satisfying completely the academic requirements for Graduateship and Corporate membership of The Institute of Physics.

Normal requirements for admission to the course will be success at G.C.E. "A" level, or O.N.C., at a high standard, in Applied Physics or Electrical Engineering.

Details of the course may be obtained from, and applications should be made to, the Registrar at the College, Cathays Park, Cardiff.

ROBERT E. PRESSWOOD,
Clerk to the Governors.

CAMBRIDGESHIRE EDUCATION COMMITTEE

CAMBRIDGESHIRE TECHNICAL COLLEGE AND SCHOOL OF ART

(*Principal:*
D. E. MUMFORD, M.A.)

DEPARTMENT OF SCIENCE

Full-time and/or part-time courses are offered for the following qualifications:

B.Sc. SPECIAL IN PHYSICS
B.Sc. SPECIAL IN MATHEMATICS
B.Sc. GENERAL
HIGHER NATIONAL CERTIFICATE IN APPLIED PHYSICS
ORDINARY NATIONAL CERTIFICATE IN APPLIED PHYSICS

G. D. EDWARDS,
Chief Education Officer.

Shire Hall,
Cambridge.

BRISTOL COLLEGE OF SCIENCE AND TECHNOLOGY

Part-time day and evening courses are offered for the following qualifications:

HIGHER NATIONAL CERTIFICATE IN APPLIED PHYSICS

GRADUATESHIP OF THE INSTITUTE OF PHYSICS

Postgraduate short courses on specialized Physics topics are held frequently.

Further details may be obtained from the Registrar, College of Science and Technology, Ashley Down, Bristol, 7

HAMPSHIRE EDUCATION COMMITTEE

FARNBOROUGH TECHNICAL COLLEGE

Part-time day and evening courses are offered for the following qualifications:—

General Certificate of Education at Advanced Level

Ordinary National Certificate in Applied Physics

Higher National Certificate in Applied Physics

Graduateship of The Institute of Physics

Further particulars from the Registrar, Farnborough Technical College, Boundary Road, Farnborough, Hants.

LANCHESTER COLLEGE OF TECHNOLOGY, COVENTRY

Principal: A. J. RICHMOND, B.Sc.(Eng.), Ph.D., M.I.Mech.E.

DEPARTMENT OF APPLIED PHYSICS

Head of Department: F. J. PEARSON, B.Sc., Ph.D., A.Inst.P.

The following advanced and postgraduate courses will be offered during the session 1961/62:—

Evening courses:
SOLID STATE PHYSICS
NUCLEAR PHYSICS
THEORETICAL PHYSICS
HIGH VACUUM TECHNOLOGY

Part-time day courses:
HIGHER NATIONAL CERTIFICATE IN APPLIED PHYSICS
HIGH VACUUM TECHNOLOGY

Short full-time courses:
THE PHYSICS OF MATERIALS
INDUSTRIAL APPLICATIONS OF ELECTRON MICROSCOPY

Further details may be obtained from the Head of Department.

NORTHERN POLYTECHNIC

HOLLOWAY, N.7. **NORth 1686**

Department of Physics—Session 1961-62

DEGREE COURSES IN PHYSICS for Internal Degrees of the University of London.

FULL-TIME AND PART-TIME Courses leading to
B.Sc. Special Physics
B.Sc. General
M.Sc. by examination.
Research leading to Ph.D. and M.Sc.

SANDWICH COURSE leading to B.Sc. Special Physics

ADVANCED PART-TIME COURSES in
Electronics and Microwave Physics
Electrical Discharges in Gases
Solid State Physics
Nuclear Particle Counting Circuits.

Selected students, with suitable degrees in Physics, may be allowed to proceed to the M.Sc. degree of the University of London.

The lectures are not confined to such students, but are open to any working in appropriate fields.

COURSES IN APPLIED PHYSICS

SANDWICH COURSE in the Physics and Technology of Electronics, leading to the Diploma in Technology, and exemption from examination requirements of The Institute of Physics and of The Institution of Electrical Engineers.

PART-TIME COURSE leading to Graduateship of The Institute of Physics (Grad.Inst.P.)

NATIONAL CERTIFICATES IN APPLIED PHYSICS Ordinary National Certificate. S.2, S.3. Course available to students of 16 or over, having appropriate passes at G.C.E. O-level, or S.1.

Higher National Certificate. Course available to students with O.N.C. in Applied Physics, and conversion course for students with suitable passes at G.C.E. A-level.

Enquiries should be addressed to The Head of The Department of Physics.

County Borough of Brighton Education Committee

BRIGHTON TECHNICAL COLLEGE

Principal: G. E. WATTS, C.B.E., M.A., Ph.D. (Cantab.), B.Sc. (Lond.), F.R.I.C.
Head of Physics Department: N. PENTLAND, M.Sc., Ph.D. (Lond.), F.Inst.P.

The following courses will be in operation during the session 1961/62:—

(A) 4-YEAR SANDWICH DIPLOMA IN TECHNOLOGY COURSE IN APPLIED PHYSICS—

Two " end-on " courses will be in operation each year with college sessions of six months' duration commencing in September or February, and alternating with similar periods in industry. Students may be either industry-based or college-based. Successful Students are granted exemption from the academic requirements for Graduate Membership of the Institute of Physics.

College sessions of courses will be as follows:—

(A) **Monday, 4th September, 1961, to Friday, 23rd February, 1962.**

(B) **Monday, 12th February, 1962, to Friday, 3rd August, 1962.**

(B) SPECIAL COURSE—

A two-day school on **REACTOR SIMULATORS.**

To be held on 5th and 6th October, 1961. Lectures and demonstrations by specialists from industry. Suitable for reactor operators, control engineers and others interested in the use of simulators for training reactor operators.

(C) ORDINARY AND HIGHER NATIONAL CERTIFICATE COURSES IN APPLIED PHYSICS—

including Conversion Year between G.C.E. Advanced Level and Higher National Certificate.

(D) GRADUATESHIP OF THE INSTITUTE OF PHYSICS—

a 2-year day release course for holders of the Higher National Certificate in Applied Physics.

A copy of the College calendar and an enrolment form may be obtained from the Registrar. Additional information on application to the Head of the Physics Department, Brighton Technical College, Brighton, 7.

W. G. STONE,
Director of Education

BATTERSEA COLLEGE OF TECHNOLOGY
LONDON, S.W.11

Department of Physics and Section of Crystallography

Undergraduate Courses

1. B.Sc. Special (University of London Internal).
2. Diploma in Technology. This course is arranged on a Full-time Sandwich basis suitable for both College and Industry based students. It consists of three years in College with an industrial year between the second and third College years. It is recognized for exemption from the Graduateship of The Institute of Physics.

Postgraduate Courses

1. Microwave Physics.
2. X-ray Crystallography.
3. Principles and Practice of Radiation Protection.

These courses consist of lectures and practical work and can be taken either full-time or part-time. Suitably qualified students may proceed to the M.Sc. (London Internal) by dissertation and/or examination (courses 1 and 2 only) or to the Postgraduate Diploma of the College. The Department of Scientific and Industrial Research has accepted these courses as suitable for the tenure of its Advanced Course Studentships.

4. Radiological Protection.

This is an evening course leading to the Diploma of the College.

5. Dislocation theory.

Research

There are vacancies for students to do research leading to the M.Sc. or Ph.D. (London Internal) in the following fields:

1. Microwave Physics
2. Metal Physics
3. Theoretical Nuclear Physics
4. Crystallography

A small number of Research Assistantships is available for suitably qualified students.

All enquiries should be addressed to

L. R. B. Elton, D.Sc., F.Inst.P., Head of the Physics Department.

ROYAL COLLEGE OF ADVANCED TECHNOLOGY, SALFORD

Department of Pure and Applied Physics

Session 1961/62

FULL-TIME COURSES

DIPLOMA IN TECHNOLOGY IN APPLIED PHYSICS A four year sandwich course. Students may be "works" or "College" based, and will spend alternate six-monthly periods in College and Industry.

B.Sc. GENERAL (LONDON)

INTRODUCTORY COURSE IN NUCLEAR POWER TECHNOLOGY — in collaboration with Harwell. Nine weeks duration.

SCIENCE AND TECHNOLOGY OF NUCLEAR POWER — eight-week course commencing May 1st, 1962.

PART-TIME DAY AND EVENING COURSES

B.Sc. GENERAL **B.Sc. SPECIAL**

H.N.C. IN APPLIED PHYSICS

GRADUATESHIP OF THE INSTITUTE OF PHYSICS

POSTGRADUATE COURSES (EVENING)

INDUSTRIAL APPLICATIONS OF ULTRASONICS

ELECTRONICS FOR THE NON-SPECIALIST

RESEARCH

Details of facilities for research and projects being studied will be sent on request.

Complete details of these and other courses may be obtained from the Head of Department.

CITY OF PORTSMOUTH COLLEGE OF TECHNOLOGY

Principal: DR. W. DAVEY, F.R.I.C.

DEPARTMENT OF MATHEMATICS AND PHYSICS
SESSION 1961-62

Full-time Courses:
External B.Sc. Special (University of London) in Physics and in Mathematics.
External B.Sc. General (University of London).
G.C.E. at " A " Level.

Part-time Courses:
External B.Sc. Special (University of London) in Physics and in Mathematics.
External B.Sc. General (University of London).
Grad.Inst.P.
O.N.C. and H.N.C. in Applied Physics.
G.C.E. at " A " Level.

Research facilities and Evening Courses on selected topics are also available.
Term commences on September 25.

Further particulars and forms of application may be obtained from the Registrar, Portsmouth College of Technology.

COUNTY OF ESSEX

SOUTH EAST ESSEX TECHNICAL COLLEGE AND SCHOOL OF ART

Longbridge Road, Dagenham. (Goodmayes 3966.)

Physics and Mathematics Department

FULL-TIME COURSES	B.Sc. General Degree. Graduateship of The Institute of Physics. General Certificate of Education, Advanced Level. Photography. Marine Radio Officers. Radio and Electronics Servicing.
PART-TIME DAY AND EVENING COURSES	B.Sc. General Degree. General Certificate of Education, Advanced Level. Photography. Ordinary and Higher National Certificates in Applied Physics. Graduateship of the British Institute of Radio Engineers. Higher National Certificate in Electrical Engineering (Light Current). Radio and Telecommunication Technician. Radio, Television and Electronic Servicing. Diploma in Mathematics. Statistics.
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Further particulars from the Head of Department

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DEPARTMENT OF PHYSICS
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Applications are invited for the above temporary research posts. The successful applicants will be required to participate in the research of a small group working on problems of brittle fracture and on the influence of adsorbed substances on the strength of solids such as silica and tungsten carbide. Applicants for the Fellowship should hold the Ph.D. degree, and applicants for the Studentship should hold an M.Sc. or Honours degree. The Fellowship is tenable for at least two years and may thereafter be renewed annually for a further two years. The Studentship will be tenable for the period of study for an M.Sc. or Ph.D. degree, subject to satisfactory progress being made. The salary attached to the Fellowship will be within the range R3060 – R3660 (£1,530 to £1,830) and the initial salary will be determined by the experience of the applicant. The salary in the case of the Studentship will be within the range R1680 – R1920 (£840 to £960) per annum for an M.Sc. graduate and for an Honours graduate will be R1200 (£600) per annum (fixed). Passage to Johannesburg will be paid to a maximum of R700 (£350) in the case of a married man and R300 (£150) for a single person. Should the member of staff leave the service of the University within two years the money so advanced is refundable on a pro rata basis. Overseas return fares will be paid at half the above rate after three years and at the full rate after four years of service. The successful applicant should assume duties as soon as possible. Applications in writing should be addressed to Professor F. R. N. Nabarro, c/o The Registrar, University of the Witwatersrand Milner Park, Johannesburg, by not later than June 30, 1961.

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UNIVERSITY COLLEGE,
IBADAN, NIGERIA

Applications are invited for two Lectureships in DEPARTMENT OF PHYSICS Appointments to commence October 1961. Salary scale: £1,200 × £75 – £1,650 (bar); £1,725 × £75 – £2,175 p.a. Passages paid for appointee, wife and up to five children under 11 years, on appointment, annual overseas leave and termination. F.S.S.U. Children's, car and outfit allowances. Part-furnished accommodation at rent not exceeding 7·7% of salary. Detailed applications (six copies) naming three referees by June 28, 1961, to Secretary, Inter-University Council for Higher Education Overseas, 29 Woburn Square, London, W.C.1, from whom further particulars may be obtained.

Applications are invited from a PHYSICIST or PHYSICAL CHEMIST to undertake research in connection with problems in food manufacture. Initial duties will be concerned with investigations into the rate of diffusion of moisture during the drying of confectionery and the person appointed will be expected to develop experimental techniques appropriate to the study. The candidate must hold a University degree and should have some experience in the conduct of research. Apply in writing to the Director of Research, British Food Manufacturing Industries Research Association, Randalls Road, Leatherhead, Surrey, giving details of qualifications and salary expected. The post carries comparable pension and life insurance rights. Applications should be marked "Private and Confidential".

UNIVERSITY OF AUCKLAND
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SENIOR LECTURESHIP AND LECTURESHIP IN NUCLEAR PHYSICS

Applications are invited for the above-mentioned posts. The Department is interested in various research fields, including angular correlation of nuclear radiations; polarized nuclear reactions; ion optics; time-of-flight neutrons. Preference would be given, other things being equal, to candidates with theoretical or experimental knowledge of any of the above fields, or similar fields. The Department has a 600 KeV Cockcroft-Walton accelerator, which will later be supplemented by a Van de Graaf accelerator (2–2·5 MeV) at present being shipped out from the United Kingdom. There are very good and rapidly increasing facilities and opportunities for experimental or theoretical nuclear research. The salary scale for a Senior Lecturer is £1,750 per annum, rising to £2,000 and for a Lecturer £1,250 per annum, rising to £1,700. Commencing salaries within these scales will be determined according to qualifications and experience. Approved fares to New Zealand will be allowed for an appointee, his wife and children, and there is a generous allowance for baggage. Further particulars and information as to the method of application together with details of Superannuation and Study Leave Schemes, should be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close, in New Zealand and London, on July 15, 1961.

EXPERIMENTAL OFFICER or ASSISTANT EXPERIMENTAL OFFICER required by ROYAL MILITARY COLLEGE OF SCIENCE, SHRIVENHAM, BERKSHIRE. To assist with laboratory classes at University level, and research. Extensive well-equipped laboratories. Should have specialist knowledge of techniques for measurement of thermal conductivity and related properties in metals especially anisotropic materials. Qualified man encouraged to do personal research for higher degrees. Quals.: G.C.E. (A level), Pass degree, H.N.C. or equiv. Age: A.E.O. 18-28, E.O. min. 27. Salary: A.E.O. £443 – £957; E.O. £1,057 – £1,296. Starting salary allows credit for approved postgrad. exp. and National Service. Opportunity for establishment and promotion. Quarters for single man, possibility of house for married man. Forms from Ministry of Labour, Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting reference A198/1A.

COMMONWEALTH OF AUSTRALIA

AERONAUTICAL RESEARCH LABORATORIES

Metal Physics

The Department of Supply invite applications for the following vacancies at the Aeronautical Research Laboratories, MELBOURNE:—

SENIOR SCIENTIFIC OFFICER **HIGHER SCIENTIFIC OFFICER**

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QUALIFICATIONS: Honours degree in Physics or Metallurgy. Several years' research experience in metal physics is essential and specialized training in the theory of dislocations would be a considerable advantage.

CONDITIONS: *Travel*—Under certain conditions, first class air/sea transport for the candidate and dependants (wife and dependent children) will be provided by the Commonwealth.
Contract Employment—Consideration may be given to entering into an agreement for a three (3) or five (5) year contract of employment in Australia. In this case the Commonwealth will bear the cost of return fares; together with the cost of removing the successful applicant's furniture and effects up to a maximum cost of £500 (Australian); £250 each way.

APPLICATIONS: Forms available from the Senior Representative (AV.104/6), Department of Supply, Australia House, Strand, London, W.C.2, with whom completed applications should be lodged as soon as possible.

Boots

Applications are invited from young graduate physicists to join a small team engaged in the industrial applications of physics.

The work involves a wide range of physical, experimental and development work associated with a variety of production processes. There is also some emphasis on special purpose instruments. A practical approach is essential.

Applications, giving full details, should be addressed to the **Personnel Manager, Boots Pure Drug Co. Ltd., Station Street, Nottingham,** quoting reference No. B.I.P.P.S.I.

COMMONWEALTH OF AUSTRALIA

WEAPONS RESEARCH ESTABLISHMENT

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The Department of Supply invite applications for the following vacancy at the Weapons Research Establishment, near Adelaide, South Australia:—

POSITION: SCIENTIFIC OFFICER, GRADE 1

SALARY: £1,510–£1,895 (*Australian Currency*).

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QUALIFICATIONS: Honours Degree in Mathematics or Physics.

CONDITIONS: *Travel:* Under certain conditions, first class air/sea transport for the candidate and dependants (wife and dependent children) will be provided by the Commonwealth.
Housing: Assistance will be given in obtaining housing accommodation.
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The Director of Research,
Research Laboratories,
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Applications outlining experience and qualifications should be sent to:

Group Personnel Services, English Electric House, Strand, London, W.C.2

Please quote reference IP 1594.K.

AUSTRALIA

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

RESEARCH STAFF

(No. 464/233)

(SEVERAL POSITIONS)

The Organization's **Division of Textile Industry, Geelong, Victoria,** invites applications for research positions from Honours graduates in Science, or Engineering with some years post-graduate research experience.

The Division, one of three constituting the Wool Research Laboratories is broadly concerned with development of new physical and chemical techniques in wool textile processing and provides well-equipped laboratories for fundamental studies and full scale mill equipment for application of results. The wide field of research includes absorption studies on wool, fibre friction, permanent setting, shrinkage prevention, mechanical action of machines on wool fibres, servo-control mechanisms in processing and development of new machines.

The appointees will carry out duties in the following fields:—

(i) Chemical studies on modification of wool fibres. This work would involve the study of reactions with a view to developing new fabric finishes;
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(iii) Physical studies on fibre friction, and the effects of lubricants;
(iv) Investigation of new methods of yarn production;
(v) Fibre behaviour in processing using radioactive and high speed photographic techniques.

Applications and enquiries from research workers in fields not strictly related to the above are also warmly invited.

SALARY: Dependent on qualifications and experience within the ranges:—
£A1,510–£A2,265 p.a. or £A2,395–£A2,720 p.a.

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(No. 464/232)

The Organization's **Division of Textile Industry, Geelong, Victoria** also invites applications for a position as Experimental Officer from graduates in Electrical Engineering, or in Science with Physics and Electronics as major subjects (or equivalent professional qualifications). Experience in design of electronic equipment is essential.

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Fares paid. *Further particulars supplied on application to:*—
Mr. E. J. Drake, Chief Scientific Liaison Officer, Australian Scientific Liaison Office, Africa House, Kingsway, LONDON, W.C.2.
to whom applications (quoting relevant Appointment number) should be addressed by **August 26, 1961**

BULLETIN
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AND
THE PHYSICAL SOCIETY

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Eddington's Fundamental Theory

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M.A., Ph.D.
University of Leeds

A lecture to the Liverpool and North Wales Branch given in Liverpool on March 9, 1961]

ARTHUR STANLEY EDDINGTON (1882-1944) has an unassailable reputation as a founder of astrophysics. His work on the combination of relativity and quantum theory and on the calculation of physical constants has a less secure reputation, but is likely to prove of equal pioneer importance. In sketching the genesis and development of this work in its historical setting, I shall perhaps overemphasize the importance of numbers in physics ; this is because interest has been attracted to Eddington's theory mainly by his calculated numbers.

I need not stress the importance of numbers to the experimental physicist, who may devote ingenious years to tying down the next decimal place. When the theoretician (perhaps the Jekyll of the experimental Hyde) seeks to tidy up the vast array of measured numbers, he may arrive at three main constituents of " physics "—

(i) *mathematical equations*, representing interrelations of observational data, either accurately or (especially when the equations embody new theoretical ideas) tentatively and approximately. These equations may often be transformed into apparently " non-numerical " *principles*, such as those expressing the absence of field inside a charged conductor, or the relativity of motion.

(ii) *numbers*—the constants of physics and chemistry; by allowing for three units of length, time and mass, or by taking non-dimensional combinations, we may think of the constants as represented by *pure numbers*. Two of these which particularly fascinated Eddington were the fine structure constant $\alpha = 2\pi e^2/(hc) \approx 1/137{\cdot}03$, and the " force constant " (the ratio of electrical to gravitational force between proton and electron) $F = e^2/\gamma m_p m_e \approx 2{\cdot}27 \times 10^{39}$.

(iii) *numerology*—sets of integers, such as atomic and quantum numbers, and those specifying crystal structure.

These three " constituents " have many cross-linkages; for example, the approximate wave-numbers of hydrogen radiation are the multiples of the Rydberg constant **R** [a number of type (ii)] by the factor $n_1^{-2} - n_2^{-2}$ composed from integers. Also, such physical constants as the recession velocity/distance ratio of the nebulae are remote from direct ideas of velocity and distance measurement; theoretical and experimental procedures are intertwined in many " constants ".

But for all this classification, physical science still lacks coherence. On the one hand, the general laws are disjointed; we have separate principles of electric force, exclusion and gravitation, uncertainty and relativity. On the other hand, despite the numerology there remains a largish collection of brute pure numbers or physical constants, apparently unrelated. Is it possible that these two types of incoherence are symptomatic, that if we could pull our principles together we should relate the pure numbers ? This is what Eddington believed and contrived—the calculation of physical constants by relating apparently diverse physical principles.

Eddington began effectively in 1917, when he received and swallowed Einstein's General Relativity. Einstein replaced the gravitational field of a mass by a curvature of the neighbouring space-time; Eddington soon accepted as a truism the identification of mass and curvature, and similarly (initially in Special Relativity) of mass and energy. This epistemology, assimilating physical principles as natural thought-processes, Eddington leaped to adopt in his thirties. Thereafter he stuck to his guns; but for a few years he was short of ammunition.

In 1926 came matrix and wave mechanics, forming with the addition of the principles of uncertainty and of exclusion a coherent quantum theory. The uncertainty principle in particular appealed to Eddington as a principle of observation, recalling the fundamental rôle of the observer in Relativity; but at first orthodox relativity procedures seemed to have only limited scope in quantum mechanics. The real break for Eddington came in 1928, with (1) Dirac's electron theory to illuminate microscopic phenomena and (2) Lemaître's cosmical expansion to relate the large to the small. I shall deal with these in turn.

Dirac's electron theory moved up from the previous single or scalar wave functions to sets of four, subjected to fourfold matrix operators; and the new wave equations

survived the space-time observer transformations of Special Relativity. Eddington produced a set of sixteen fourfold matrices—or *E*-symbols — which incidentally made patent the relativistic properties. Why sixteen? — primarily because a general fourfold matrix has sixteen elements, and so requires a set of sixteen basic matrices for its description. Eddington developed *E*-number calculus in his own way, largely independently of its mathematical prehistory; and similarly nearly all his algebra has been re-developed and accepted by " orthodox " quantum physicists for their own purposes. The use Eddington made of this calculus was, however, more startlingly unorthodox. He largely accepted the substantial body of quantum principles which had (by 1930) been developed and linked with experimental data; this involved new physical constants such as the quantum h, the fine structure constant and the masses of particles. Eddington set himself to co-ordinate the principles so as to derive or explain the constants. He regarded this as involving not so much calculation as *enumeration* — the enumeration of the number of relevant degrees of freedom of physical entities.

The *E*-number calculus was used mainly as a tool for this enumeration. Of the sixteen *E*-symbols, ten are imaginary, represented by symmetrical matrices, and six are real and antisymmetrical; these can represent an elementary particle with ten mechanical and six electrical freedoms. For a pair of particles we use the outer product of two sets of *E*-symbols; of the products, $10\times10+6\times6=136$ are real and in a sense symmetrical, and the others mixtures. Eddington began in 1928 with the wave equation for two electrons; the pure number in this equation is $\alpha=2\pi e^2/hc$, which was then near 1/136. So his first guess was that $1/\alpha$ was to be identified with the effective dimensionality of a two-electron system. How could this be relevant ? $2\pi e^2/hc$ comes in because of an electric potential proportional to e^2; what has this to do with dimensionality ? But two electrons have to face an Exclusion Principle as well as Coulomb's law of repulsion ; if now we identify exclusion and repulsion, the electrons could have effectively 136 ways, or degrees of freedom, for excluding each other, and this suggests the relation $2\pi e^2/hc=1/136$. As Eddington wrote at this point: " There are weak places in the deduction, where the conceptions become too hazy to guide us definitely; but by that time we seem to be well in sight of the goal, and may have confidence to make the necessary jumps ". In his later papers he took Coulomb energy to be equivalent to interchange energy, and raised the constant $1/\alpha$ to 137 to allow an additional degree of freedom representing interchange or confusion of identity. Another dimensional investigation led to a quadratic equation

$$10m^2-136m_0m+m_0^2=0, \qquad (1)$$

the ratio of whose roots in m he considered to represent the ratio of the masses of proton and electron (primarily as constituents of the hydrogen atom).

The result of Lemaître (and Friedmann) was that, after indefinite expansion, the ratio speed/(separation distance) of elements of an Einstein universe approaches

$$V_0=c/R_0\sqrt{3}. \qquad (2)$$

The Einstein universe is a uniform model of a (General Relativity) universe having a mass $\pi c^2/(2\gamma)$ times its initial radius R_0; if it is set expanding from this radius, the expansion continues. If the real universe is of this type, we may identify V_0 with the velocity/distance ratio of the nebulae (with a correction for an estimated shortfall from the limiting state). Observational estimates of V_0 then give R_0 through equation (2), and so the total Einstein mass, and thence N, *the number of particles in the universe*, assuming it to be equivalent to a collection of hydrogen atoms. The number so found is about 10^{79}.

That is how Eddington began. Assuming now that any one particle may be anywhere in the universe, it has an uncertainty of position of the order R_0; and a co-ordinate of the mean centre of *all* the N particles has a standard deviation (using the values of R_0 and N calculated as above)

$$\sigma=R_0/2\sqrt{N}\approx10^{-13}\text{ cm}. \qquad (3)$$

This is presumably the least uncertainty of position of any physical origin of measurement; so that if two particles coincide we should measure them as being about a distance σ apart. This creates an observational "force" of about this range, which Eddington considered to represent " non-Coulombic " nucleonic force. The constant σ as a fundamental length was expressed by Eddington also as an exact numerical multiple of $\mathbf{R}^{-1}$, where $\mathbf{R}$ is the Rydberg constant mentioned earlier. Thus the recession velocity gives the Rydberg constant. I had pointed out in 1947 that the constant in equation (3) above should be 3, not 2; this upset the agreement between the directly observed value of $\mathbf{R}$ and the calculation from V_0, until Baade's revision of the scale of galactic distances altered V_0 so as to restore (for the time being) the agreement.

To complement the non-cosmological mass-ratio quadratic (1), Eddington gave three cosmological-quantum combinations to determine the mass M of a standard particle or hydrogen atom (which is (136/10) times the reference mass m_0 of (1)). The first method involved the momentum distribution conjugate to the position uncertainty discussed above. The second method involved the Exclusion Principle. Here he regarded the $\frac{1}{2}N$ particles as put into successive quantum states, of which the lowest has the whole circumference $2\pi R_0$ of the universe for wavelength; the energy or mass of an observable particle should correspond to the top level, namely

$$M=\frac{136}{10}\frac{3}{4}\frac{h}{2\pi}\frac{1}{R_0}\left(\frac{4}{5}N\right)^{\frac{1}{2}}, \qquad (4)$$

a result given also by the first method (and in agreement with the measured hydrogen mass). A third method (which he did not develop in this context) treated rest mass as an interchange angular momentum of extra-spatial rotation, or of " confusion of identity ".

After his first treatise, *Relativity Theory of Protons and Electrons* (1936) which begins with *E*-number theory, Eddington concentrated on the " statistical theory ", in which gravitational rather than spin phenomena are of main interest. Here he systematised his use of the dimension numbers 10, 136 and 137 by a theorem based essentially on the idea of Hartree's self-consistent field. Eddington viewed the total energy of a particle system as divided into particle energy and field energy, the

latter representing the disturbance created in the environment. A variation of the scale or plan of measurement (for example by ignoring internal strain motion) requires for consistency of the field that the energy ascribed to the particles should vary *inversely* as the number of observable degrees of freedom. Eddington's final version of the mass-quadratic (1) is based on this theorem, but has a " renormalization factor " $(137/136)^{5/6}$ in the last term, to correspond to the rôle of the extra 137th (interchange or electrical) degree of freedom in practical methods of measuring the mass-ratio.

In 1941-44, Eddington wrote some five consecutive versions of a book on these developments. The last version was published under the title *Fundamental Theory* chosen by the editor, Sir Edmund Whittaker; I have compiled a summary of the earlier versions as *The Development and Meaning of Eddington's Fundamental Theory*. The later chapters of *Fundamental Theory* give some " simple applications ", such as the calculation of nuclear masses and moments; it must be borne in mind that elementary particles were at that time less numerous, and also that Eddington disallowed the meson field.

Although Eddington did not reach a planned chapter on Epistemological Theory in this last version, much of a similar chapter survives from an earlier version. This has an analysis of the nature of measurement and of observables, leading to the calculation of the number of standard particles as the number of conceptual occupants of measurable states. This plays the rôle of the number N of particles in the universe in calculations which conceptually involve them all; it is $N = (3/2) \times 136 \times 2^{256} = 2{\cdot}32 \times 10^{79}$. Eddington used this in preference to the approximate value derived from galactic recession, so that his scheme of calculated constants became self-contained.

In this draft chapter there is also a statement of Eddington's epistemological position. The following quotation makes this fairly clear:

> " Physical science might be defined as ' the systematization of knowledge derived by measurement '. . . . Since actual measurement is limited by practical difficulties, there are large gaps in our knowledge, and the data of measurement are commonly supplemented by hypotheses — hypotheses as to what would be the results of the measurements we are unable to make. . . . But there is one part of physics entirely free from hypothesis; this part deals with the properties possessed by measures simply because they *are* measures — not conditioned by the object to which measurement applies. This may be called *epistemological physics*; but it appears from the investigations in this book that epistemological physics is co-extensive with *fundamental physics*; that is to say, it comprises all of the general ' laws of nature ' and the constants contained in, or deducible from, them ".

Eddington is claiming that physical laws and magnitudes are deducible from an analysis of the nature of measurement. In effect he reproduced the observed values of physical constants by moderately plausible combinations of the principles of measurement and of the generalizations built up from the experience of generations of experiment and theory. One should hardly attempt now to correct Eddington's detailed arguments merely by refinement and algebraic rigour; field, particle and nuclear physics has moved on too far. But the Eddingtonian spirit has now — perhaps unconsciously — permeated much of physics, so that in Liverpool, as formerly in Eddington's Observatory House, mass-ratios are becoming calculable. Perhaps with the recent edge that radio astronomy has given the finite Einstein-type universe over the continuous-creation infinite universe, a fresh impetus will be given also to the study of the relation of the cosmos to the particle.

The question remains whether this sort of thing will ever reach a terminus — whether we shall ever settle for a physical structure which still contains " irrational " elements of law and numerical magnitude. If our minds are merely constructs of that same physical world which they seek to explain, we shall presumably go on rationalizing. But there may be more to mind than this; and we may reach a point of decision at which we may accept the existence of the irrational in the physical universe.

Bulletin of The Institute of Physics and The Physical Society

The Fate of Ph.D. Physicists

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IT IS common knowledge among those responsible for the training of Ph.D. physicists that very little information is readily available which gives an overall picture of the supply and subsequent fate of this rather special class. Even such vital numbers, such as for example the number of physics Ph.D's trained each year, are by no means generally known. Many definite opinions about what happens to these Ph.D's are held and often forcibly expressed, but these for the most part are based on impressions gained in one particular laboratory, impressions which are apt to be quite false.

To provide a more reliable statistical assessment of the physics Ph.D. situation, I asked the heads of the 35 university physics departments in Great Britain for the following information:—

" 1. The numbers of research students in your department who were *awarded* Ph.D's in experimental physics between October 1955 and October 1960.
2. How the theses were distributed according to subject.
3. The first employer of these people (after subtracting the foreign students who returned to their own countries).
4. The subsequent fate of these people, field of work and employer ".

The response to my questions was overwhelming. In just over two months I have had replies from all 35 physics departments. I know from my own experience of digging out the information here in Liverpool that this represents a good deal of somewhat tedious work, and I am very much aware of the debt of gratitude I owe to the heads of these physics departments.

Before presenting the results of this " Gallup Poll " I think the following comments should be made. I asked for Ph.D's *awarded* so that I would get unambiguous numbers. At any moment there is always a large number of Ph.D's " in the pipe-line " and I did not want the picture to be confused by their being included. This means too that those postgraduate students who have actually completed the work for their theses but who, for some reason or another, will never present the work for a Ph.D. have been eliminated. Again, I asked for information about *experimental* physicists in order to present as clear a picture as possible. Nevertheless, a few theoreticians, I believe, have crept in ! I have not included, simply because it appeared difficult to get the information, people who have taken an external Ph.D. from the University of London. Not included either, on the grounds that they form a very special class, are those who took their Ph.D's in physics departments attached to hospitals and medical schools. I asked for foreign students who had returned to their own countries to be subtracted before any figure was given. In spite of this, most departments gave me this information as well and it turns out to be most interesting.

The total number of Ph.D's awarded in the 35 departments in the years 1955-60 was 859, i.e. 172 a year. This number is almost identical, on a *per capita* basis, with the corresponding number for the United States, where, of course, strenuous efforts are being made to improve the situation. If we say that the average research life of a Ph.D. physicist is 15 years, this annual rate of production would lead to a stable population of Ph.D. researchers in the United Kingdom of 2560. 15 years does not seem to me unduly pessimistic; by that time the poorer ones have dropped out of research and the better ones have become administrators.

From these numbers another interesting figure can be derived, namely, the annual production of Ph.D's per university staff member. One can estimate the numbers of staff from the D.S.I.R. annual publication *Scientific Research in British Universities*. In the latest volume, which is for 1958-9, there are listed " permanent members of the university staffs actually engaged in supervising research ". Including Heads of Departments, this number for physics was 467. Since 467 staff members produce 172 Ph.D's a year, the annual rate of production is 0·37 Ph.D's/staff member/year. It should be stressed perhaps that besides training postgraduate students virtually all members of university departments will be engaged also in the teaching of undergraduates. In this country there is no separation of institutions which teach only up to the first degree level and those which run only postgraduate schools.

Again, the rate of production for the small physics schools (< 10 staff members) is significantly lower than for the large ones (> 10 staff members). The respective numbers are 0·30 and 0·41 Ph.D's/staff member/year. The small numbers from the smaller schools are almost certainly due to the larger burden of undergraduate teaching that the staff members there carry.

To deal here with the foreign students, I was given details of 126 who took Ph.D's here and returned to their own countries. The actual number must be larger than this because I had asked specifically that this information should not be included. In any case, these 126 (16% of 859) represent a most valuable contribution which this country is making to the development of countries overseas. Contrariwise, I was given details of five students from abroad who took their Ph.D's here and who stayed in this country, and there might be a further 10 or 11 in this category that I have no precise information on.

Details of the thesis subject of 674 Ph.D's were sent to me and I have reproduced a digest of this in Table 1. I should make it clear that the titles in this table are actually those which were sent to me. It is clear that quite often similar physics will be described by different titles and vice versa. But any further interpretation

seemed to me very difficult and I have simply accepted the descriptions I was given. The "Miscellaneous" categories of Table 1 include those subjects for which there were less than five candidates. I am confident that from this table everyone will be able to invent his own horror-story — "Do you know we produce as many Ph.D's in . . . . . as in . . . . . ?"

NUMBERS OF PH.D. THESES

Table 1

Atomic and molecular physics		
Solid state	100	
Solid state and low temperatures	27	
Low temperatures	21	
Optical spectroscopy	33	
Radio-spectroscopy	16	
X-ray physics, spectroscopy, crystallography diffraction	30	
Nuclear magnetic resonances and electron spin resonances	10	
Magnetism	34	
Metal physics	8	
Semiconductors	5	
Plasma physics and gas discharge	22	
Miscellaneous	10	
		316
Nuclear physics and cosmic rays		
Low energy nuclear physics	114	
High energy nuclear physics	66	
Cosmic rays	45	
		225
Other branches of physics		
Shock waves in gases	5	
Atmospheric physics	16	
Ultrasonic/acoustics	16	
Electron physics	6	
Electron diffraction	7	
Rock magnetism	6	
Technical optics	20	
Biophysics	9	
Nuclear alignment and cooling	10	
Miscellaneous	38	
		133
GRAND TOTAL		674

The present employment of 604 of the 853 Ph.D's from 1955 to 1960 is shown in Table 2. A certain amount of caution is required in drawing conclusions from these figures. The first warning is about those listed under "Universities". The universities are the only employers who go in for any sizeable numbers of temporary appointments, so the 27% who are at present in university employment will probably not all stay there.

Table 2

Present employment of Ph.D's

Government Service	156	26%
Industry	132	22%
Universities	167	27%
Abroad	108	18%
Other	41	7%
	604	100

It seems to me that all these figures could be useful to anyone interested in the "demographic" problems of physics. For example, it is interesting to try to estimate whether the present rate of recruiting physicists to the universities is anything like adequate to cover the proposed two-fold expansion in physics students in the next ten years. One can make a rough estimate in the following way. Suppose that the total staff in physics departments is 1·25 × those "supervising research". This would lead to a total staff of 580. If their average working life is 40 years then in ten years we shall lose 146. Therefore in the next ten years we shall have to recruit 580 + 146 = 726. The present rate of recruitment is 27% of 859 in five years, i.e. 460 in ten years. So assuming that all the 27% stay in the universities the present rate of recruitment is still quite inadequate for the proposed expansion. The universities clearly will have to make more strenuous recruiting efforts if they are to meet the expansion they have undertaken.

Another interesting category is those 18% of Ph.D's who are abroad. This, of course, is a very large number and I have received a number of comments on it. Clearly, this number is only meaningful if one knows also how many stay abroad permanently, and how long those who eventually will return to this country spend overseas. This last figure is important simply because the research life of a physicist is usually rather short and he is often at his most productive in the 15 years, say, which follow his Ph.D. If most of the 18% spend one or two years abroad then this period of time could be certainly regarded as an essential part of their training. But if in fact they are spending longer, then this could be a serious loss to the country, if we regard Ph.D. physicists as a national asset.

To get some insight into this problem I first looked at the numbers from those departments who had given me the first employment *and* present employment of their Ph.D's, and this information is given in Table 3. However, in this analysis the number of those at present abroad is exactly the same as those whose first employment was abroad. In fact, a number of those whose first employment was abroad have returned to this country, but they have been exactly counterbalanced by those who took up their first employment in this country and *subsequently* went abroad.

Table 3

First and present employment of Ph.D's

	1st Employment	*Present*
Government Service	90	83
Industry	99	89
Universities	102	104
Abroad	80	80
Other	22	37
	393	393

Another line of attack on this problem was possible in that some departments had given me records of individuals rather than overall statistics. Among those were 92 whose first employment was abroad, and of these 21 had returned to this country, suggesting that the average stay abroad is about four years. Certainly all the indications are that this question of Ph.D. physicists

going abroad for a long period or even for ever is a serious one, but it is clear that to reach a reliable conclusion one would need more and different data than those I have analysed here.

A small but interesting point to be extracted from Table 3 is that there is a fairly definite drift from the Civil Service and Industry into " Other ", and " Other " in this sense is almost entirely Technical Colleges.

There are two points I should make that have a bearing on whether the 1955-60 figures are typical. The first is that 1960 was the first year when graduates were completely free from National Service obligations, and this will probably be reflected in the future in a diminution of those entering Government Service, and, to a lesser degree, Industry.

The second point is that the annual production of Ph.D's is clearly not time-independent and is probably increasing. My own statistics are not sufficiently detailed to make any very significant comment on this. Nine departments gave me year-by-year details and the average annual production for 1955/60 in these places was 33. In 1959/60 these places produced 42 Ph.D's but I suspect this number was artificially high because people were not observing to the letter my request for Ph.D's awarded. It is clear that these numbers are too small to draw strong conclusions from.

I feel that although the figures I have managed to collect are somewhat fragmentary, the results are sufficiently interesting to justify a rather more professional approach to this collecting of information. It seems clear that a body like the Institute of Physics and the Physical Society would find itself amply repaid if it could invest some secretarial effort in this.

To sum up, then

1. The number of physics Ph.D's produced per annum in the U.K. is surprisingly small, 172/year.
2. The rate of production per staff member " supervising research " is 0·37/year. This means that in a 20-year career " supervising research " a university physicist will produce just over seven of his own kind
3. A large number ($>16\%$ of all Ph.D. physicists) of postgraduate overseas students are trained in this country and subsequently return to their own countries.
4. Those physicists who take up their first employment in this country are fairly evenly divided between the universities, the civil service and industry. So in spite of the complaints from industry voiced to the Kemmer Committee, industry seems to take its share.
5. The number of physicists going into university employment is certainly insufficient if the proposed expansion in university physics departments is to take place.
6. Physicists are going abroad in sufficient numbers and for sufficiently long times to constitute a serious drain on the national resources. To estimate just how serious would require another enquiry.

Appeal for the Physics Trust Fund

The following donations or subscriptions were received between April 25 and May 23, 1961:

(*a*) From Members

Mr. F. G. Brightman	Mr. J. C. King	Mr. P. E. Slater
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The total received or promised by May 23, 1961 (including those previously announced) was:

	£
Gross value of industrial firms' covenants over seven years (including tax recoverable)	99,503
Single donations from firms	7,490
Total from Industry ...	106,993
Gross value of 232 members' covenants over seven years (including tax recoverable)	5,056
Single donations (316) from members...	799
Total from members ...	5,855
GRAND TOTAL at May 23, 1961 ...	£112,848

June 1961

The Correlation of Metrical Properties of a Physical System

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A PHYSICAL "system" comprises a restricted region of the world which is the subject of investigation in terms of certain designated variables that are considered as metrical properties of that system. To decide just what variables are relevant to the problem of describing a particular system requires an insight for which no universal rules of procedure can possibly be given, but once having chosen at least two variables, x and y, the specification of the system can be made in terms of a functional relationship between them, a $y = f(x)$ or $\emptyset(x, y) = 0$. It will be shown that a functional relation can be developed which expresses a number of the important aspects of the general experimental method that aims to establish the actual form of the relationship between the designated variables. The method of derivation of the final equation follows that of Prescott[3] and is a more specific formulation of a number of the aspects of Reichenbach's discussion of the principle of causality and the discovery of governing functions[4 p. 114].

The simplest limiting case can be considered of two metrical properties x and y of a system in which the correlation is perfect, i.e. in which every value of x determines a precise value of y, then

$$f(x, y) = 0 \qquad (1)$$

In general, in describing any actual physical or chemical system, it will be the case that there are a larger number (t) of relations between a larger number of variables, so that

$$f_i(x, y, z, \ldots) = 0 \text{ where } 1 \leqslant i \leqslant t \qquad (2)$$

Amongst the variables there will be some that are independent and from which the others can be determined. Indeed, in general there will be a series of relations containing dependent variables in terms of independent variables, but it is unnecessary to elaborate on this distinction which can be arbitrarily made and indeed is so often made on the score of convenience alone. It is sufficient for our purposes that there be at least one relation between at least two variables, one of which can be classified as independent and the other as dependent.

Consider the independent variables of a system as its parameters (x) sufficient to determine the dependent variables which can then be considered as the derived properties (p) of the system. Then from (2), by considering one derived property p and n independent parameters $(x_1, \ldots x_n)$,

$$p = f(x_1, x_2, \ldots x_n) \text{ where } 1 \leqslant n \leqslant \infty \qquad (3)$$

The analysis must be restricted to a system in which p is an independently measured property, i.e. its method of measurement is completely independent of any procedure involving the independent parameters and the functional relationship between them. A simple illustration of this type of system would be the comparison of the volume of a sphere calculated from a functional law relating it to a measured parameter such as the diameter, and the volume measured by an independent practical procedure such as displacement.

Equation (3) can be rewritten as :

$$| \; p - f_i(x_1 \ldots x_n) \; | = 0 \qquad (4)$$

i is merely a subscript indicating a serial order of the function within the hierarchy of functions which may be developed progressively in the attempts to bring the experimental and theoretical values of a property p into closer correspondence. An example would be the earlier gas equations developing from Boyle's law (f_1) to the general law (f_j) to van der Waal's equation (f_k).

In actual practice it is generally the case that the exactness indicated by (4) does not pertain (indeed it will be shown that it is unattainable). Let Δ represent some small finite quantity that is the departure of the experimental value of p from that value calculated by means of the form of f_i from the measurements $x_1, x_2, \ldots x_n$.

$$\text{Then } | \; p - f_i(x_1 \ldots x_n) \; | < \Delta \qquad (5)$$

for a correlation between theory and practice to be considered to exist.

Δ may conveniently be expressed as one of the standard statistical quantities such as the probable error, the modulus of precision or the ratio of the experimental error to the range. The latter expression indicates how it is that an increase in accuracy of measurements of the n parameters can become unwarranted and ineffectual when Δ has reached the theoretical minimum which cannot be reduced for that particular value of n. Increasingly accurate measurements are not necessarily a guarantee of higher degrees of correlation that may require f_i to f_j to f_k and so on by increasing n. This increase must, of course, be in the dominant or determinative parameters which "correspond to other relevant causes" [4 p. 115] which need elaboration so that n is comprehensive yet small enough to be amenable to the practical attainment of an acceptably low value of Δ.

An example of this sort of procedure is obtained by considering such equations of state as those of Dieterici, Clausius, Berthelot, Reinganum. All these equations and several others of similar type, if expressed in the form in which pressure is the dependent variable, contain four independent variables. Hence no one of these equations could be expected to be more universally applicable than another, nor indeed to make any really significant advance (in either accuracy or range of

application) on van der Waal's equation since $n=4$ in the latter case also. These various equations of state have become subsumed under the so-called "virial" equation, the number of terms in which can be varied in accord with the degree of accuracy desired. Such terms are virtually correction factors added to the ideal gas equation and whilst originally based on empirical evidence only or on an inadequate theory (as with van der Waal), have now come to be understood in terms of interactions between progressively increasing numbers of molecules.

Equation (5) indicates that p has been assumed to be determined theoretically by the measurements of a limited number of n parameters, which are those that have been measured and incorporated into the relationship,

$$p_{\text{calculated}} = f(x_1 \ldots x_n) \text{ where } 1 \leqslant n \leqslant \infty.$$

But p as a metrical property of the world has parameters beyond reckoning since all observations are only samples of nature and all forms of sampling give only probable information about the population from which the sample is drawn.

$$\text{Hence, } p_{\text{observed}} = f(x_1 \ldots x_\infty).$$

With p represented as a function of its infinite number of parameters so Δ_n can be considered as a measure of the deviations in p due to the $x_{n+1} \ldots x_\infty$ parameters which have no representation in f and so

$$\Delta_n \to 0 \text{ as } n \to \infty.$$

The final complete expression can now be written as:

$$| p(x_1 \ldots x_\infty) - f_i(x_1 \ldots x_n) | < \Delta_n \qquad (6)$$

This functional relation shows how it is that no quantitative description of a system fully comprehends reality since such a description is based on a small number of independent variables whilst any real phenomenon depends in actuality on an infinity of parameters. The mathematical identification of the function requires an infinity of terms, but the series provided by experiment is always finite. Such a conclusion has also been reached by other procedures as in Brillouin's discussion of information theory and his conclusion that "it is quite impossible to eliminate experimental errors completely . . . they represent an absolutely unavoidable feature of the experimental method"[1].

By the well-known principle of superposition of errors it is possible to calculate a value of the experimental error δp in p due to the experimental errors in the measurements of the various independent parameters $(x_1, x_2, \ldots x_n)$.

$$\text{Thus } \delta p = \sum_{i=1}^{i=n} \frac{\partial p}{\partial x_i} \delta x_i \qquad (7)$$

If the consecutive errors can have values between $\pm e_1$, $\pm e_2 \ldots \pm e_n$, then the most probable value of δp can be ascertained from :

$$(\delta p)^2 = \sum_{i=1}^{i=n} \left(e_i \frac{\partial p}{\partial x_i} \right)^2 \qquad (8)$$

Hence within a given system in which the errors in measurement of each parameter is known, it is readily possible to arrive at a theoretical range of values within which the measured values of p should fall (this merely expressing what is really only the standard technique of an accurately performed and closely controlled experimental verification).

It is suggested that when there is an "acceptable" agreement between $p_{\text{calculated}}$ and p_{observed} according to normal experimental standards, then it is the case that the values of Δ_n and σp are comparable (when both are similarly expressed). It may also be the case that an arbitrary parameter is introduced in order to obtain this sort of agreement between the experimental and theoretical values of a metrical property of a system. A recent example of this procedure is the use of a "remainder" term as a percentage correction in the theoretical equation for the calculation of electron affinities of negative atomic ions, such a term lacking as yet any theoretical significance.[2]

In the preceding analysis, it has been shown how the limiting precision of the correlation, viz. Δ_n depends on the mode of the description in terms of the n parameters. It may be the case that a fine structure is discovered in the phenomena that necessitates a different mode of description in terms of a group of new variables $z_1 \ldots z_m$. The quantities $p\,(x_1 \ldots x_n)$ and $p\,(z_1 \ldots z_m)$ are the same metrical property of the world referred to two different modes of analysis. The degrees of freedom of the phenomenon are not greater than n and thus the m z's may enter a functional relationship only in terms of n functions $\theta_1 \ldots \theta_n$ which are statistical functions of the $z_1 \ldots z_m$ variables. So to the same degree of correlation, equation (6) can be rewritten with a developed function f_j as :

$$| p(x_1 \ldots x_\infty) - f_j[\theta_1(z_1 \ldots z_m) \ldots \theta_n(z_1 \ldots z_m)] | < \Delta_n \qquad (9)$$

Such a representation shows the possibility of the co-existence of two modes of analysis within the same region of correlation, one devoted to group phenomena, the other to particular phenomena. Analysis of the former is made in terms of those metrical parameters that correspond to statistical functions of the particular variables. Examples of this kind of relationship are frequent in physics, as in such a case as the kinetic theory of gases and thermodynamics. In these cases statistical transformations connect the fine and the group phenomena, both of which are metrical aspects of nature.

REFERENCES

1. Brillouin, L., *Nature*, 183, p. 501 (1959).
2. Johnson, H. R., Rohrlich, F., *Nature*, 183, p. 244 (1959).
3. Prescott, C. H., *Phil. Sci.*, 5, p. 237 (1938).
4. Reichenbach, H., *Modern Philosophy of Science*, Routledge and Kegan Paul, London (1959).

Communication—Physics for the Non-Specialist

[A Summary of the Education Group, Easter Conference, April 6-7, 1961 at Headquarters]

THE purpose of the Conference was to consider the communication of scientific information (with particular reference to physics) to middle school pupils who had not yet specialized and specialists studying or working in other fields. Some 60 people were in attendance, all but ten of whom were employed in education.

The account which follows gives the impressions of an individual member of the Conference and is not primarily intended as a summary of the papers presented.

The programme consisted of an introductory lecture, three lecture-discussion sessions and a final discussion. All speakers agreed that there was a need for communication as outlined above in view of the significance of science in society. One speaker mentioned the slogan " Physics is Life ", which he had seen during a recent visit to Russian schools, to indicate the importance which other countries place on the activities of physicists—but this is anticipating particular sessions.

The introductory lecture on Communication was given by Professor G. P. Meredith of the Department of Psychology, University of Leeds, who told the conference that he was a physicist turned psychologist. He said that his subject was concerned with psycho-physics and likened language to a form of radiation which carried information from one person to another. He saw communication to consist of three galaxies: a communicator, a recipient and an intermediate body of existing culture from which the communicator could draw a vocabulary for sending information to the recipient. A similar system would be employed for visual communication. A successful act of communication depended on a large overlap of the vocabularies known to the communicator and recipient; this would cause many resonances in the receiving system. Any lack of resonance needed to be corrected by a feed-back system —conversation—by which the recipient could examine the intention of the communicator. Professor Meredith elaborated on this model and pointed out that our knowledge of the nature of language needed improvement to provide markedly more efficient communication. He stressed the essential practicality of his theory and mentioned the importance of informal conversation as a means for the individual to increase his knowledge of the intermediate body of culture. One could see this latter process in operation during the coffee, lunch and tea breaks. The sessions that followed were specific and dealt with particular aspects of communication.

The first session was devoted to middle school pupils. Dr. H. F. Boulind of the Department of Education, University of Cambridge said that three questions should be considered: Why communicate? What to communicate? and How to communicate? His answer to the first question was that the pupil should gain an insight into scientific method and learn to make intuitive steps in his understanding of nature. One should communicate physics—present day physics—and not physics for those who would take O level, followed by A level, followed by a university physics course. Here Dr. Boulind had an opportunity to point out that the proposed syllabus from the Science Masters' Association set out to provide a basis for teaching physics as a living subject rather than a tradition examination subject. On the question How? Dr. Boulind stressed the need for practical work, the use of short films designed as a part of the course (few of the right length were available) and outside classroom activities such as science societies—one must in fact tempt the recipient, an idea to be echoed later. Dr. Boulind finished by mentioning difficulties in providing a physics teaching programme—shortages of material and laboratory stewards; the need for new textbooks and examinations for his proposed syllabus and finally the small number of teachers available and small proportion of the national income devoted to education.

Mr. J. Scupham, Head of Educational Broadcasting, British Broadcasting Corporation, after explaining that he was a non-scientist, said that he would deal primarily with communication by television. He mentioned later that sound broadcasting still had powers of appeal to the imagination when subjects such as the history of science were treated. He began by ruling out the system of science teaching, used in parts of the United States of America, in which television reduced the teacher to a child minder—the vital feed-back link was missing. The B.B.C. provided programmes which were intended to assist the teacher, but not replace him. Programmes needed both illustrations and words; diagrams could deal with spatial relations but words were needed for conceptual problems outside this field. Sight being the predominant sense, there was the danger in a television programme of fogging the main coherent presentation. There was always the need for the verbal element to keep a balance between the use of the two senses. The expositor of a programme must have a suitable personality and be prepared to explore the possibilities of presentation. He had a number of powerful tools—models (e.g. of the atom), animated diagrams (e.g. convection currents), the opportunity to give a " front row seat " (e.g. look down a microscope) and films to show principles in use in industry. Mr. Scupham mentioned that mathematics provided few possibilities for educational television. At least one member of the audience had forgotten by the end of this contribution that Mr. Scupham was a non-scientist—perhaps the desired communication could, after all, be achieved.

During the discussion on this session the needs of the secondary modern school were emphasized and some mention made of the means of meeting their particular needs. Professor Meredith stressed the importance of practical work in showing the reality of physics and this gave an opportunity for Dr. Boulind to be challenged on his suggested use of nuclear fission rather than coefficient of expansion in a physics course. Dr. Boulind replied that there was need to be up-to-date with a living subject and Mr. Scupham added that the idea of the scientist

as a mystery man must be removed. On the note that many middle-intelligence pupils have short memories, but even so communicating science to them may still be important, the conference adjourned for lunch.

The afternoon was devoted to arts sixth-formers and university students. Mr. J. Lewis of Malvern College in an energetic contribution told first of his impressions of educational establishments in the Union of Soviet Socialist Republics and Germany—in the former he had read " Physics is Life " and " Work, work, work " on the classroom walls and in the latter had an erudite lecture-demonstration on radioisotopes from a pupil at a Gymnasium for Classical Studies. One thought of Dr. Boulind's closing remarks in the morning. Mr. Lewis went on to describe his experiences at Malvern in providing a course in nuclear physics and radioactivity for the arts sixth form. Mr. Lewis claimed that the student could learn something of the " fun of physics " in a branch of the subject that enabled him, with little mathematics, to make measurements, learn of problems such as wave/particle duplicity, and appreciate the history of science as well as moral problems. One had little doubt that Mr. Lewis's enthusiasm would be a large factor in achieving his aims. He went on to describe typical experiments involving statistics and field work which could be carried out with safety and at low cost.

Dr. D. E. Davies, F.Inst.P., followed with a description of the four year course at the University College of North Staffordshire, in which a student takes lectures in a discipline other than his own. This was the only contribution in which visual aids were used and Dr. Davies reminded his audience that a lantern slide can carry much factual information. He explained that in the foundation year a student with A levels in, say, mathematics and physics who proposed to read these two subjects, often extended his specialist knowledge of a narrow branch of physics such as electronics as complementary to a broader approach in his other discipline. Potential students of the humanities, on the other hand, would have a more general course in physics. Dr. Davies stressed, as had Mr. Lewis, the need for giving students some idea of the precision of measurement and mentioned that useful training could be given with such simple operations as finding the density of odd shaped pieces of brass all cut from the same sample !

The discussion on this session showed that many schools introduced science to arts students through the history of science, if only for the reason that no apparatus was needed. However, Dr. Boulind remarked that the main function of such courses for arts pupils was to teach physics, not history and the formal business of the conference ended for the day.

Communication to non-scientific adults was considered on the second morning. Dr. T. Margerison, Science Correspondent of the *Sunday Times* contended that one cannot automatically expect the layman, " top person " or otherwise, to want to learn about science. In his own case the only way to make him a gardener was to introduce the subject in an interesting fashion in a paper he habitually read ! This technique, he thought, was well understood by the television authorities, but poorly by the newspapers. Was it not true that only one national daily paper carried even a weekly science article. The layman thus had no alternative to the fairly " stiff " articles of publications such as the *New Scientist* and *Discovery*. The purpose of a newspaper was to carry news and a science article would be sure of a place in the paper when it was also " news " Dr. Margerison cited the case of Professor Ryle's work. He spoke of the difficulty of writing for the public on subjects such as chemistry and solid-state physics where a great many background facts must be assumed—isolated advances, based on a smaller field of background knowledge, were more amenable material.

Mr. J. McCloy speaking as Science Producer in the Talks Department of the B.B.C. Television Service, told of the size of his audience. A lecture before a capacity audience in the Royal Institution would have to be repeated every night for fifty years to reach as many people as one programme. He felt that the overriding consideration must be to make the scientist and his work real. The scientist must not be portrayed as a magician on a stage with a proscenium arch between him and his audience. The person to make direct communication on a science programme was a scientist who would be willing to make generalizations his audience could understand. In this connection the differing attitudes of research physicists and research doctors were contrasted; the doctor was often too willing to generalize, but after all he was used to dealing with the public! Mr. McCloy thought that television could communicate science as part of the body of knowledge and was admirably suited to show science at work and the attitude of scientists. He spoke of the need for programmes that were suitable for the middle intelligence groups. Mr. McCloy interspersed his talk with telling and amusing anecdotes drawn from his own experience—here was the scientist with a streak of showmanship.

The discussion following this session was lively and included arguments between the speakers themselves and the audience on a variety of topics, such as the ideal person for presenting science on television; should there be professional technical writers for communicating science; the merits of different science programmes and the small number of science correspondents employed by the press. One was forced to realize that the speakers were men whose vocation brought them into contact, albeit indirect, with the " general public " and not captive pupils or students.

The afternoon discussion was, in the event, largely concerned with details of specific problems in schools. The question of secondary modern schools again occurred —they had four times as many pupils as the grammar schools and had been given relatively little attention as far as science courses were concerned. Those sensitive to potential " markets " could not afford to ignore such a challenge—perhaps only the educationalist could! The conference had come to an end. Could one expect to be any the wiser, and what does wiser mean anyway ? The opportunity had been given to learn of other people's experiences and problems in communicating science to the non-specialist with plenty of opportunity for more and less formal discussion. The purpose of the conference had been achieved.

R. F. Y. Randall.

Notes and News

Despatch of Communications

The opportunity provided by amalgamation has been taken to modernize the whole of the records system of the Institute and Society and to install new equipment for the addressing of notices, journals and other communications to members. The installation of this system has involved a good deal of work and, since new address stencils have been prepared for all members, a few errors may have to be corrected. The new arrangements will, however, greatly reduce the possibility of errors in the future and will reduce the cost of administration by saving staff time.

Members will have noticed that it has now been possible to arrange for all publications to be despatched in envelopes instead of wrappers, a change which many members have requested in the past.

Modern Trends in Physics

A course on modern trends in physics, designed for teachers preparing students for university entrance, is to be held at University, College London, during the week July 3-8, 1961. Full details can be obtained from Mr. D. J. Johnston, Adviser to Teachers, University of London Institute of Education, Malet Street, London, W.C.1.

The Physics of Graphite-Moderated Reactors

The Institute and Society, in collaboration with the British Nuclear Energy Conference, is sponsoring a Symposium on "The physics of graphite-moderated reactors" to be held in Bournemouth on April 4-6, 1962. The provisional program includes a half-day's visit to the Atomic Energy Establishment at Winfrith, Dorset. A number of papers have already been promised and further contributions will be considered by the Committee. The Symposium is intended particularly for the less senior members of research and development staffs working in this field. First preference to attend will be given to members of the constituent bodies of the British Nuclear Energy Conference, one of which is the Institute and Society. Communications about the Symposium should be addressed to the Secretary of the Institute and Society at 47 Belgrave Square, London, S.W.1.

Handbook of Scientific Instruments and Apparatus 1961

The *Handbook of Scientific Instruments and Apparatus* published in connection with the 1961 Annual Exhibition of the Institute and Society is now out of stock. As it is still in very great demand we should be very grateful

The Thomas Young Oration

will be given at 6 p.m. on

JULY 11, 1961

at the

IMPERIAL COLLEGE OF SCIENCE AND TECHNOLOGY, LONDON

by

Dr. H. H. HOPKINS, F.Inst.P.

on

Applications of frequency response techniques in optics

Tickets are not required. The lecture is open to all interested.

The Institute and Society,

on behalf of

The International Union of Pure and Applied Physics and the British National Committee for Physics

is arranging a

Conference on the

Physics of Semiconductors

at the

UNIVERSITY OF EXETER

on

JULY 16-20, 1962

It is expected that applications to attend will exceed the accommodation available and early application is therefore recommended. Details will be available before the end of June, 1961, and may be obtained from the Administration Assistant of the Institute and Society.

if any member who has a copy for which he has no further use would return it to the Institute and Society, at either Belgrave Square or Lowther Gardens. The proceeds of re-sale will be added to the Institute and Society's Benevolent Fund.

Summer School in Health Physics

A Summer School in Health Physics (Radiation Protection), arranged by Dr. Hugh D. Evans, A.Inst.P., will be held in the Department of Chemical Engineering and Chemical Technology, Imperial College, London from July 3, 1961 to July 14, 1961. The course is designed to provide basic information on principles. It is suitable for graduates in science or medicine and should be of interest to radiation protection officers in the universities or in industry, medical officers of health, factory inspectors and others concerned with radiation protection. The fee is 25 guineas. A few places are still available and applications for admission should be made to the Registrar, Imperial College, South Kensington, London, S.W.7, from whom further information may be obtained.

Forthcoming Institute and Society Meetings

Date	*Place*	*Speaker*	*Title and other details*	*Time*	*Branch or Group*
June 16	**Manchester** Literary and Philosophical Society		All day meeting on **Spectroscopic studies using time resolution techniques** Registration is necessary	10.30 a.m.	Applied Spectroscopy
June 17	**Scarborough** High School for Boys	Mr. N. Clarke, F.Inst.P. (*The Institute of Physics and The Physical Society*)	Summer Meeting and Lecture **The winds of change in physics education**	11.00 a.m.	Yorkshire
June 24	**London**		**Summer meeting and visit to Royal Naval College, Greenwich** Registration is necessary	11.00 a.m.	London and Home Counties
June 30	**Winfrith** Atomic Energy Establishment		Summer Meeting — Visit to Atomic Energy Establishment Registration is necessary		South Western
July 10 to 12	**Durham** The University		Symposium on **Thermoelectricity** Registration is necessary. Programs and application forms may be obtained from Professor D. A. Wright, F.Inst.P., Department of Applied Physics, Science Laboratories, South Road, Durham.		
July 10 to 14	**London** Imperial College		Conference on **Optical instruments and techniques** (arranged under the auspices of the International Commission for Optics by The British National Committee for Optics)		Optical
July 10 to 14	**Nottingham** The University		Annual Conference Registration is necessary. Programs and application forms may be obtained from the Administration Assistant of the Institute and Society.		Electron Microscopy
July 11	**London** Imperial College	Dr. H. H. Hopkins, F.Inst.P. (*Imperial College*)	**Thomas Young Oration** **Applications of frequency response techniques in optics**	6.00 p.m.	
July 19	**Camden Town** and **Debden**		All day visit to Hilger & Watts Ltd. factories. Registration is necessary		Education

RADIO SPECTROSCOPY OF SOLIDS

The Institute and Society jointly with the British Radio Spectroscopy Group is arranging a conference on " Radio Spectroscopy of Solids ", in the Department of Physics of the University College of North Wales, Bangor, on September 21-22, 1961.

The Institute and Society's Guthrie lecture will be presented during the Conference by Dr. D. Shoenberg, F.R.S., who will speak on :—

The de Haas-van Alphen effect and the electronic structure of metals

Residential accommodation will be available. Programs and application forms may be obtained in mid-July from the Administration Assistant of the Institute and Society.

ELECTRON MICROSCOPY GROUP

The annual conference of the Electron Microscopy Group

will be held at the

UNIVERSITY OF NOTTINGHAM

from July 10 to July 14, 1961

The main topics to be discussed are :

Electron Microscopes and Electron Optics—Past, present and future trends—Microscope devices and attachments.

Electron microscopy of thin films—including carbon, metal films, metal physics, magnetic domain theory, etc.

The theory and scope of electron diffraction methods.

Miscellaneous techniques and applications on electron microscopy.

The last day of the conference will be devoted to a symposium on " The physics of sectioning and the embedding process ".

It is intended to arrange an exhibition of apparatus and micrographs. Offers of exhibits should be sent to the Honorary Secretary.

Programs and enrolment forms are available from the Administration Assistant of the Institute and Society.

ELECTRONICS GROUP

Conference on

THE PHYSICS OF GAS DISCHARGE DEVICES

September 28 and 29, 1961

at

LEAMINGTON SPA

Topics to be considered will include:

Energy measurements in modulator thyratrons—comparison of the properties of hot cathode thyratrons containing the three isotopes of hydrogen—non-thermonuclear applications of high temperature discharges—problems of arc control—heavy current switching—very high current mercury pool switches—thermionic energy converters—gas-filled thermionic converters with ion injection—gas discharges as wave propagation devices—stabilizing tubes—corona stabilizers—surface emission of electrons by secondary processes in gas discharges.

A limited number of hotel rooms are available but bookings cannot be guaranteed after July 1. Information regarding hotel bookings and programs and application forms may be obtained from the Administration Assistant of the Institute and Society.

The Institute and Society is arranging

a Symposium on

" Some aspects of the physics of space research "

to be held at the

Royal Military College of Science, Shrivenham

from

20 - 22 September, 1961

Subjects to be discussed are:

The advantages to physicists of space research;
Cosmic rays, particle physics and meteorology
Physical techniques in space research
Rockets, orbits and trajectories

The symposium will be residential. Further details may be obtained from the Administration Assistant of the Institute and Society.

Reviews of Books

THERMODYNAMICS

By Herbert B. Callen

New York: John Wiley & Sons Inc., London: Chapman & Hall Ltd. Pp. xv+376. Price 70s.

This book stands out among textbooks of thermodynamics for two reasons. In the first place it is a new way of developing the subject, starting from four basic postulates dealing respectively with equilibrium states and internal energy, entropy of a single system, the entropy of a composite system, and fourthly the vanishing of entropy at absolute zero of temperature. The subject is developed deductively from these postulates. This is probably a good formal way of teaching thermodynamics, although it tends to remove it rather further away from experimental observation than the classical methods. The second outstanding feature of the book is that it has a whole part dealing with fluctuations and irreversible thermodynamics, and with the applications of these ideas to thermoelectric and thermomagnetic effects. The author is fully aware of the fact that the whole of classical thermodynamics is in fact thermostatics, and carries this last part as far as possible into the field of true thermo dynamics.

Typical of the author's approach is the fact that the whole development of the subject can be carried out without ever once asking the question, " but what is entropy ? " However, he is helpful enough to provide a special appendix answering this question for the benefit of those readers who, like your present reviewer, do ask just this kind of question. All the diagrams are well and clearly drawn, but they are mathematical physics rather than experimental physics in the sense that they are the type of diagram one draws on the blackboard to show the way the curves go, and do not contain any experimental observations.

M. W. Thring.

RADIOACTIVE WASTES — THEIR TREATMENT AND DISPOSAL

General Editor: John C. Collins

London: E. & F. N. Spon Ltd. Pp. xxi+239. Price 55s.

The continuing accumulation of fission products and other noxious substances released through the exploitation of nuclear energy raises a difficulty rather like that which confronted the aborigine who, having received a new boomerang for his birthday, spent the rest of his life trying to get rid of the old one.

Pollution of the environment is a nuisance that has been with us since coal began to be used as a fuel seven centuries ago. Disposal of radioactive wastes presents new problems which are, fortunately for the public health, being tackled with greater vigour and insight than were ever applied to any of the earlier hazards. Physicists, chemists and engineers are all involved; a knowledgeable consortium have combined in writing this book which brings together a great deal of expert advice and judgment.

The first half of the book deals with the scientific basis of the dangers arising from the preparation and use of radioactive materials. The longest and most detailed chapter in this section discusses the hazards of radiation; others are concerned with the nature of radioactivity, the sources of radioactive wastes and the measurement of radioactivity. The next major topic is the treatment of radioactive wastes. Traditional methods of filtration, precipitation and biological concentration are important because they are widely available, though modifications are needed when radioactive effluents are under treatment. New techniques, such as fusion in glass or ceramic materials are also explained. Finally consideration is given to methods and precautions associated with the disposal of radioactive rubbish in solid, liquid or gaseous form.

In general the treatment is full and thoroughly competent. The only disappointing feature is the meagreness of the chapter devoted to legal aspects. The law relating to radiation hazards is admittedly incoherent and a flood of fascinating litigation is only restrained by the fact that production, assessment and control of the hazards are almost entirely in the hands of government departments or agencies. The brief synopsis provided in the present volume could in future editions be usefully augmented by a commentary from a barrister or a teacher of law.

Leaving aside this suggestion, the book is an admirable compendium of information and guidance; it should be available to all who use radioactive materials for scientific, industrial or commercial purposes.

J. M. A. Lenihan.

ELECTRICAL THEORY ON THE GIORGI SYSTEM

By P. Cornelius (translated from the third Dutch edition by L. J. Jolley)

London: Cleaver-Hume Press Ltd. Pp. x+187. Price 32s.

In the preface the author claims that he explains electrical theory simply and intelligibly in this book by having the courage to break with tradition and use the Giorgi (m.k.s.) system of units. The exposition is said to be " adapted to the mental outlook of the technician, the engineer and the experimental physicist ".

Starting with electrical conduction the reader is led, with the help of analogies and imaginary experiments, to consider the parallel-plate condenser and thus to accept the simpler ideas of the electric field. By similar artifices we are introduced to magnetic flux, electromagnetic induction and magnetic field strength. The introduction of Maxwell's displacement current concludes Chapter 1.

The second chapter deals with m.k.s. mechanics and gives the formulae for the forces (in newtons) in various systems of charges and currents, though no attempt is made to relate these facts to the ideas already given. Chapter 3 consists largely of propaganda for the Giorgi system and follows the usual lines. Chapter 4, entitled " Selected Problems in Electrical Theory ", is designed to convince the reader that field strengths and flux densities are quantities of different natures—an article of faith in treatments of this kind—though in fairness one must admit that many of the problems (transmission lines,

aerials, generators, magnets, etc.) are inherently useful.

The final two chapters are devoted to dimensions and conversion factors. One might truly say that the Achilles' heel of the c.g.s. electrical units is their dimensions, and the author does not hesitate to expose this weakness, together with the superiority of the m.k.s. system in this respect.

The convenience and tidiness of the m.k.s. system are beyond doubt, but no physicist worthy of the name would buy these advantages at the expense of logical rigour and the ability to define his terms unambiguously. " The complete system of lines of force " is the only definition of magnetic flux given before we are introduced to the law of electromagnetic induction in the form $\Phi = \int V.dt$ (p. 25), though the author tries to help later by stating that " these volt-seconds are represented by the magnetic flux which surrounds the field ". Countless further examples of loose thinking and obscure expression could be quoted from all parts of the book, which belongs to that class of writing in which physics is represented as a collection of facts of unknown origin. It is a matter for regret and apprehension that this type of instruction (" physics without tears ") is becoming increasingly advocated even in circles where its results are most disastrous.

K. A. MACFADYEN.

TECHNICAL OPTICS. 2nd Edition of Volume II
By L. C. Martin

London: Sir Isaac Pitman & Sons Ltd. Pp. vii + 391. Price 63s.

Professor Martin's pre-war book *An Introduction to Applied Optics* was enlarged and republished in two volumes in 1948 and 1950 under the title *Technical Optics*. The second volume of this work has now been revised and enlarged again to take account of the important advances both in optical theory and in instrumentation that have occurred during the past ten years. Readers familiar with the earlier editions will know that the book is based on the lectures given, in parallel with courses on the techniques of optical designing and computing, during a postgraduate course in Technical Optics. It is thus concerned more with general principles—albeit at a high level—than with specific details.

The subjects covered—and indeed the chapter headings—remain the same; telescopes, microscopes, binocular instruments, photographic lenses, photometry of optical systems, the testing of optical components and aspheric surfaces are all fully treated in both editions. In the new edition the chapter on the microscope includes short accounts of a number of systems of interference microscopy and a brief, but important, section on the place of the partial-coherence concept in the proper understanding of the diffraction theory of image formation. There has been a considerable enlargement of the section on optical testing and it now includes scanning methods, Dyson's common-path interferometers and shearing interferometers. The other principal addition is a useful and lucid summary of the theory of contrast transmission given in a new appendix. The author has taken the opportunity of revising the main text in places. For example, the term " resolving power " has been replaced by " resolving limit " and discussions on depth of focus and depth of field have been clarified. The bibliographies at the end of each chapter have been expanded and brought up to date (the total number of references has, in fact, been almost doubled) and, possibly because of a change in the paper, the print is much clearer and easier to read.

Professor Martin manages to achieve completeness and clarity without unnecessary mathematics. Historical allusions have not been ignored and this feature is especially welcome in a field which has involved some extremely colourful personalities over the last three hundred years or so. In spite of the title the whole flavour of the book is that of physics, useful, readable physics.

C. A. TAYLOR.

THE MAJOR ACHIEVEMENTS OF SCIENCE
By A. E. E. McKenzie

London: Cambridge University Press. Vol. I. Pp. xvi + 368. Price 30s. Vol. II. Pp. xi + 195. Price 17s. 6d.

Mr. McKenzie set out to write a history of science in which each chapter would be followed by the appropriate extracts from original books and papers. As the work progressed, however, and grew in size, he decided, quite rightly in my opinion, to publish these original extracts as a separate volume, which now forms vol. II of the combined work.

Considering first vol. I, Mr. McKenzie has succeeded in writing a very interesting and readable history of science in which a chapter is allocated to significant forward steps in each of 19 branches of science, ranging over the whole field of natural science, but excluding technology, over the period 1500 to the present day.

His opening chapter deals with science and also technology in ancient and medieval times up to the Renaissance, and in 15 pages gives a remarkably comprehensive account of this wide field of human endeavour.

In the 19 chapters which form the bulk of the book the emphasis is on the whole on achievement by individuals, but the purely personal side is not overdone and the logical development of each subject is never lost. Twelve of these chapters are of direct interest to the physicist, namely those on the Copernican theory, the mechanical universe, the pressure of the air, the early microscopists, the atomic theory, the wave theory of light, the conservation and dissipation of energy, field physics, the structure of the atom, the theory of relativity, the quantum theory and cosmogony.

The book also contains general chapters on the 17th, 18th, 19th and 20th centuries, and in these Mr. McKenzie switches the emphasis mainly to the philosophy of science. In the last, for instance, he considers the relationships of Mach's positivism, Peirce's pragmatism, Poincaré's conventionalism and Marxist dialectical materialism, and discusses also the impact of Einstein's theories of relativity and of the quantum theory on the idea of causality in science.

He also describes briefly the recent developments in the organization of scientific research for social purposes.

In his preface the author states that his book is essentially a history of scientific ideas, and hopes that it will prove of interest to students of the humanities in sixth forms and at the universities.

Personally, I find it an accurate and stimulating history of science, and a book which is informative and

can be read with real pleasure. It is adequately but not profusely illustrated by well-chosen plates and diagrams.

Volume II consists of a total of 91 extracts from original writings of the scientists whose work is described in volume I. These are not necessarily the author's original papers but are more commonly drawn from later essays or lectures in which the author describes his original work in more general terms and sometimes relates it to earlier work or defends it against criticism. The extracts are well selected and are varied, many being from sources not otherwise readily accessible. They run in the same sequence as Mr. McKenzie's own descriptions in volume I, and are very sparsely illustrated with line drawings.

Both volumes are well produced and set in an easily legible type, and together they form a welcome addition to the general literature of the history of science.

F. A. B. WARD.

ELECTRODYNAMICS OF CONTINUOUS MEDIA

By L. D. Landau and E. M. Lifshitz. Translated from the Russian by J. B. Sykes and J. S. Bell

Oxford: Pergamon Press Ltd. Pp. x+417. Price 84s.

As the various volumes of this great work come out in English translation the precise measure of its greatness is revealed more and more. One can only repeat over and over again that there is nothing to compare with it in modern times, not only in its scope but in the unity of the conception of theoretical physics lying behind it. Considerably earlier in the course, in the volume *Classical Theory of Fields*, the reader became acquainted with Maxwell's equations in vacuo and with the interaction of electromagnetic fields with charged particles (treated fully relativistically). But the interaction of electromagnetic fields with actual matter was not touched on then. Conventionally, the relevant theory is divided into two parts, phenomenological theory and atomistic theory. A student will learn normally about such things as dielectric constants, permeabilities, conductivities and how they enter the equations either without reference to any atomistic justification in or (one hopes more usually) with a fair amount of reference of a descriptive kind but nonetheless without a full atomistic foundation. By arranging their course in the order they have chosen, Landau and Lifshitz approach this side of electrodynamics only at the stage when the student should have the full apparatus of thermodynamics, kinetic theory and statistical mechanics available to him. They are therefore able to give a far sounder justification to phenomenological theory than is normally possible and they avoid completely the normal situation in which a full treatment is given only of the simplest cases, while all the more complicated situations are left out as being capable of exact treatment only on a more sophisticated level. Thus we have here, for instance, the first introduction to the simple concept of an isotropic dielectric followed immediately not only by similar treatment of the anisotropic dielectric but also of pyroelectricity, piezoelectricity and ferroelectricity. It is also made quite clear from the start that the usual volume integral expression is to be understood as the free energy and not the total energy of the system. This mixing of what we are accustomed to think of as elementary and as advanced comes into evidence even earlier. The first chapter has the conventional title "Electrostatics of Conductors", and indeed this is where the reader is introduced for the first time to such things as the method of images, inversion, and all the other "elementary" notions of potential theory. But this happens *after* a sound discussion of what it really means physically to assume that one may treat a conductor as bounded by a sharp geometrical surface carrying a surface charge density.

So it goes on. Following on the chapter on dielectrics we get, as in any conventional treatment, a chapter on steady currents, but this chapter treats not only Ohm's Law and its consequences, but also the Hall effect, electrocapillarity, thermoelectricity, etc. Perhaps the only omission that struck the reviewer was that there is not even a mention of conduction of electricity through the vacuum, the space charge equation, etc. Of course, this branch of the subject does not strictly fit under the heading of this volume but where else in the course will it be treated?

The chapter on constant magnetic fields contains a quite detailed treatment of the magnetic symmetry of crystals and, as everywhere else, all the necessary thermodynamics is covered. Gyromagnetic phenomena are also dealt with here.

Having thus characterized the level of treatment that is consistently maintained, I shall merely mention the next few chapter headings: Chapter 5—Ferromagnetism, Chapter 6—Superconductivity, Chapter 7—Quasi-static Electromagnetic Field, Chapter 8—Magnetic Fluid Dynamics. Although of course the subject of this last chapter has grown enormously in the recent past and cannot be covered completely here, the 26 pages devoted to these matters are at the same high level as the rest. The next three chapters deal with electromagnetic waves, and cover not only dispersion theory, geometrical optics, resonators and wave-guides, diffraction, to pick out but a few topics, but also electromagnetic waves in anisotropic media. The last four chapters are more diversified again, they are entitled Chapter 12—The Passage of Particles through Matter, Chapter 13—Electromagnetic fluctuations, Chapter 14—Scattering of Electromagnetic Waves and, finally, Chapter 15—Diffraction of X-rays in Crystals.

It has been impossible for the reviewer to pick out more than a few headings to indicate the richness of the whole work. It may be felt by some that the feast is too rich and indeed he must be a good physicist who is equally at home in all of the fields here covered. Without doubt, however, theoretical physics as a whole owes a great debt of gratitude to the authors yet again for making this presentation available and to the reviewer's mind there can be absolutely no doubt that this volume, like all its predecessors, will remain unique and indispensable for many years to come.

N. KEMMER.

UNITS, DIMENSIONS AND DIMENSIONLESS NUMBERS

By D. C. Ipson

London: McGraw-Hill Publishing Co. Ltd. Pp. vii+236. Price 50s. 6d.

This book follows somewhat the same lines as the best accounts given in textbooks of physics (for example,

in Champion and Davy's *Properties of Matter*), starting with the need for units in describing physical phenomena in concrete terms. It then explains how simple units are combined to form more complex units, like those of viscosity, how to convert units and illustrates how the requirement that an equation must permit changes of size of units limits its form. Discussions of similitude, dimensionless relations, dimensional analysis, dimensionless numbers and comparison of geometrically dissimilar systems, follow naturally. As nearly always with this subject the treatment is essentially by illustration (and not demonstration) and this contributes to the length of the book. For although, as is pleasing to see, the author does not obscure the subject with pseudo-philosophical discussion (as has happened before with this subject), it *is* a long book. Some trimming could well add forcefulness to the style of writing, which is otherwise attractive. The paper, printing and binding are excellent.

The opportunity to review this book also provides, if the Editor allows, an opportunity to make some comments on the subject. The essential point, which is usually made by implication, is that if primary measurements are made on arithmetic scales by addition of concrete units, the derived units have dimensional formulae of the form $A^a \cdot B^b \cdot C^c \ldots$. If the primary unit to which the symbol A is applied is doubled in size the number by which a measurement of a quantity of the same kind as the concrete primary unit is specified is halved, but the derived unit is increased in size by the factor 2^a, and the numbers specifying the derived quantity are reduced by the same factor. This is a matter of observation. When it is treated as a matter of observation only then an element of mystery remains, which has led to misgivings and speculations about supposed inner meanings of dimensions. But it can also be shown that it is not only a matter of observation but inevitably so, if we choose, as we may, the simplest, arithmetic, scale for measuring derived quantities. We can, therefore, cease to worry about magic and use dimensions as what they are, namely, a useful mathematical tool.

E. W. H. Selwyn.

X-RAY ANALYSIS OF ORGANIC STRUCTURES

By S. C. Nyburg

New York and London: Academic Press Inc. Pp. xii + 434. Price 93s.

This book is written by a chemist for chemists. It is, however, worth reviewing in this *Bulletin* because the author sets out to explain the physics of X-ray diffraction, and it is interesting for physicists to see how this is attempted. The author's approach is to use diagrammatic illustrations as far as possible, and his explanations of such topics as the co-operative scattering of the electrons in an atom or the atoms in a unit cell are very good. But when anything mathematical is treated, the author usually says " It can be shown that . . .".

The book should be useful, therefore, for the non-specialist organic chemist or biochemist who uses the results of crystal-structure determination and wishes to know something of the way that they are obtained. One would have thought, however, that a less detailed book would have sufficed; the price is very high for a research worker to pay for a book which is only incidental to his own line. Perhaps, however, there is compensation in what appears to be a very thorough review of organic structures in the second half of the book and the large number (about 1000) of references which the book contains.

There seem to be only a few mistakes and reprints. One figure, however—that on p. 121 showing the agreement between a transform and a weighted reciprocal lattice—is quite wrong.

H. Lipson.

THE SEARCH FOR ORDER

By C. J. Schneer

London: The English Universities Press Ltd. Pp. xvii + 398. Price 21s.

In this book we have yet another attempt to look at the foundations of natural science, and so to help those whose interests are chiefly in the humanities to grasp something of the significance of thought about the universe and the world in which we live. In principle, all these efforts are to be commended. They soften up, if they do not remove, artificial barriers between subjects, and sometimes even start valuable chains of intercommunication. The pages now before us try to do this by emphasizing what may briefly be called the order-disorder problem. It is ever with us, and many of the best brains have tackled it at one time or another. Greek civilization lasted for something like a thousand years, and Hebrew culture a very long time. Between them they provided the scholastics of the middle ages with material for a grand synthesis which, outmoded as it may be, remains a precious heritage for contemporary natural philosophy. Through all this, mankind has travelled from sheer chaos (combined with what Sir James Frazer in *The Golden Bough* called the black thread of magic) through crude atomism, mechanism, and materialism—including the fruits and disappointments of the French " Enlightenment "—to the caution characteristic of the twentieth-century.

All this, Professor Schneer describes. It is difficult to feel sure that he has been wholly successful. Probably, nobody could be. But amid much that is valuable, he wanders off into historico-social asides a little too often, taking up space better devoted, maybe, to deeper analysis. For example, his discussion of thermodynamics is impressive (especially the remark that this sublime discipline grew out of the study of the heat-engine, and not the other way round). But why not make a thorough job of it, and introduce the reader to the third law (Nernst's theorem), and the axiomatic use of Pfaff's equation ? They are not more difficult than many other topics which the author considers. Thus the vista presented by revealing the whole building is lost to us, not to mention the likely extensions to it by general system theory, and the virtual denial of the classical concept of Boltzmann's *Wärmetod*. In contradistinction to this, however, the account of the development of field-theory—illuminated strongly by that ingenious eighteenth-century Adriatic Jesuit, Boscovitch—is singularly complete. Moreover, it brings out how intuitive it was for Faraday, and how perfectly mathematical for Clark Maxwell. Never should one judge between these two types of insight. Both are precious in their quest for order.

Fig. 25 (caption) is a little misleading. We do not, in fact, in the strict sense, " see " Brownian particles in motion. The resolution would never permit. This is a mere matter of words, and does not affect the point, which is to compute Avogadro's number.

If they had time, sixth-form pupils would benefit from this volume, whatever their main pre-occupations. It might be useful to ask them to write a " review " of it as an essay. The results would probably indicate not so much the coming winners of open university scholarships, as the good all-rounder, who was destined to contribute something to this insistent quest for order in the structure and life of the world.

F. I. G. RAWLINS.

LABORATORY MANAGEMENT AND TECHNIQUES

By J. A. Edwards

London: Butterworths Publications. Pp. xvi + 207. Price 35s.

Mr. J. A. Edwards is Superintendent of Laboratories, Chemistry Department, at Birmingham University. He has devoted his life to laboratory management, which seems to be almost a traditional profession in his family; his father had similar duties at Manchester University, and his grandfather was at Balliol College, Oxford.

The book is divided into six parts:—I. The New Laboratory (Design, Equipment, Stores); II. Laboratory Organization and Maintenance; III. Accident Precautions; IV. Special and Auxiliary Units (Radioactive Materials Laboratory, Lecture Theatre, Photographic Processes, Workshops, Library); V. Purchases and Records; VI. Staff Problems ad Human Relations.

The scope of the book is very wide for its size; in fact, much too wide to enable such subjects as laboratory design, building, and organization to be discussed adequately. The subject-matter would normally be presented in two separate books directed at different classes of readers; one of interest to Laboratory Directors and Managers dealing with design, organization and staff, and the other of interest to Laboratory Stewards dealing with maintenance, storekeeping, safety, and laboratory arts and crafts. Incidentally, there seems to be some confusion in regard to the title of the person responsible for what is really laboratory " housekeeping". It is stated (p. 196) that " in large laboratories or institutions this work is usually carried out by one who may be given the title of Steward, Superintendent, Secretary, Administrative Assistant, or Manager." In many industrial laboratories the word Manager or Superintendent or Secretary has a very different meaning.

The author rightly keeps a wary eye on costs; " the money required is contributed directly or indirectly by a long-suffering public " (p. 3), and " more than half the cost of a science laboratory goes down the drain " (p. 164). The latter statement does not of course apply to an industrial laboratory—here more than half the cost goes into salaries.

He does not have a very high opinion of the scientific personnel. " Many laboratory workers seem to have a very hazy idea as to the necessity for adequate storage space " (p. 6); and the research worker's workshop " is usually under the care of an older technician sufficiently knowledgeable to prevent the academic laboratory worker from doing much harm either to himself or to the tools " (p. 157).

In discussing the heating of the laboratory, it is stated (p. 11) that floor heating has not become popular, but radiators or convectors are generally considered the most satisfactory form of heating. In the reviewer's experience, floor heating is very suitable for the smaller laboratories, and has the advantage that it leaves the walls completely free for benches or equipment.

The book is concerned mainly with chemistry laboratories but a great deal of the information is applicable to science laboratories in general. It gives much sound advice, and abounds in useful hints and tips. It will be of great help to the Laboratory Steward, particularly in universities, technical colleges, and schools, and it should also serve as a textbook for young people taking up laboratory work.

J. S. FORREST.

ELECTRONIC FUNDAMENTALS AND APPLICATIONS

By John D. Ryder

London: Sir Isaac Pitman and Sons Ltd. Pp. xii + 721. Price 60s.

This volume provides a general account of electron devices and circuits, and endeavours to explain their behaviour. The applications referred to in the title are limited to power supplies, amplifiers, oscillators, modulation and wave shaping. The first chapters are concerned with the basic physics of electron motion and charges in matter, and they are used to explain the characteristics of vacuum tubes and semiconductor devices. There is also a chapter on four-terminal network theory which is subsequently made use of in the sections dealing with amplifiers.

In the preface the author claims that in this edition it is intended to reflect the belief that the transistor and other semiconductor devices have now fully proved themselves and that such devices should receive a treatment fully parallel with vacuum and gaseous devices. It is extremely difficult to achieve this purpose in a modification to an existing text. On the whole, this attempt has been fairly successful. Even so, the general sections devote very much more space to valves than to transistors.

In a book of this kind it is difficult to decide how far back to go in basic physics. In some cases the starting point appears to be somewhat arbitrary. For example, in dealing with the theory of the p-n junction the author assumes the formula for the barrier potential in terms of the carrier densities, and proceeds to derive the expression for the current flow. One would have expected to have some discussion of the physical significance of the assumed formula. Again, in the derivation of the Child-Langmuir equation for space-charge-limited current in diodes there is the assumption of negligible field at the cathode, without any physical justification. With such evasion it is doubtful if there is any point in the analysis.

Although physicists may find the early sections on basic principles rather inadequate, this book does provide a good general account of electron devices and their associated circuits and it goes some way to emphasize that transistors and other semiconducting devices have arrived.

M. R. GAVIN.

The Register

ELECTIONS TO MEMBERSHIP

THE FOLLOWING ELECTIONS WERE MADE BY THE COUNCIL ON MAY 2, 1961

An asterisk (*) indicates transfer from another grade

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Thornley, John Harry Maute, B.A., Research Student, Magdalen College, Oxford.

Wilson, Raymond Neill, B.Sc., Ph.D., Senior Research Assistant, Optics Department, Imperial College, London.

Twenty-seven Students and three Subscribers were also admitted.

† We regret to have to record the sudden death of Mr. Steele.

Manuscripts accepted for publication in the Institute and Society's periodicals

British Journal of Applied Physics

Rheology of granular material II — method for the determination of the intergranular cohesion. By M. M. Benarie.
The intergranular cohesion of granular masses is investigated with an apparatus which in principle is a Couette viscosimeter. Rheologically, the granular mass behaves as a plastic solid, with the difference that the plastic yield point S_c of a granular mass is a function of the pressure p which acts normally on the yieldingplane. In an S_c–p diagram, a cohesionless mass will be represented by a straight line passing through the origin and having a limiting slope of 0·193, while a granular mass with cohesion will show a lesser slope, the departure from the limiting value being a convenient measure of the cohesion. Powders which are not free-flowing, will be represented in the S_c–p diagram by not necessarily straight lines with an intercept on the S_c axis.
The cohesion of a few samples of sand of different granularity and that of a few other granular masses has been measured.

Sorption and replacement of ionized noble gases at a tungsten surface. By R. B. Burtt, J. S. Colligon and J. H. Leck.
Experiments are described in which ion beams of the order of five microamperes with a low energy spread have been used to bombard a tungsten surface. Sorption values for the surface are given for neon, argon and krypton and show that a maximum sorption exists at any particular bombarding ion energy. Using several simplifications a value for the depth of penetration of the ions is derived from the results and this is shown to be in reasonable agreement with values quoted by other workers. Results from a second series of experiments where ions of a second gas release the sorbed ions of the first gas are also presented.

Study of the performance of dielectric thin film beam dividing systems. By L. A. Catalan and T. Putner.
A theoretical and practical study has been made to compare the optical performance of single layer $\lambda/4$ TiO_2 and double layer $\lambda/4$ MgF_2 – $\lambda/4$ TiO_2 coatings when used as beam-dividing systems. Theoretical and experimental values of the spectral response for light arriving at normal incidence and at 45° incidence are given together with the values for reflectance as a function of angle of incidence for monochromatic light. The optical characteristics of glass–film–glass beam dividing systems are also investigated. It is further shown that the efficiency of a system consisting of a reflecting single $\lambda/4$ layer between glass boundaries is improved by the introduction of a second λ 4 low refractive index film layer.

Measurement of electrical resistivity by a mutual inductance method. By R. G. Chambers and J. G. Park.
The resistivity of a sample can be deduced from the change in mutual inductance between two coils when the sample is inserted. It is shown that, with simple equipment for measuring mutual inductance over a range of frequencies, the method can be used to measure resistivities from 2×10^{-8} ohm cm upwards, and the necessary functions are tabulated.

INVITED ARTICLE

Physics of the ocean. By G. E. R. Deacon.
A hundred years ago better navigational instruments, improved charts and the compilation of wind and current atlases brought much improvement to navigation. In comparison the advances made by modern instruments and theoretical methods are second-order steps, but they are just as exciting, and with the increased pressure of to-day's civilization and industry, probably more important. In particular we are beginning to get a better understanding of waves, currents and the general circulation in the oceans, which will allow us to make better use of the oceans, and to contend with them on more equal terms when necessary.

Bandwidth of a moon communications circuit. By J. V. Evans.
Radar studies of the moon by a number of workers have shown that the principal reflections occur from a region at the centre of the visible disk having a radius of about one tenth that of the moon. Thus it is possible to use the moon as a reflector in a communications system, and several successful systems of this type have been demonstrated. This paper describes measurements made at the Jodrell Bank Experimental Station to determine the single channel bandwidth of the system using double sideband amplitude modulated transmissions. It is found that the demodulation of the signals caused by the multiple scattering at the moon's surface restricts the bandwidth to about ± 1 kc/s, although the demodulation does not appear to increase rapidly at higher modulation frequencies.

Photovoltaic response of selenium barrier layer cells to x-radiation in the energy range of 15–40 kev. By R. Feinberg and G. E. Rhead.
Twenty selenium barrier layer cells made by a modern commercial process with a variety of modifications, were examined with irradiation of x-rays in the 15–40 kev energy range and the behaviour was compared with their response to light. The x-ray sensitivity is found to be independent of intensity of irradiation at constant x-ray tube anode voltage but linearly proportional to anode voltage at constant anode current. The form of transient response to x-irradiation depends on the intensity of irradiation and the previous history of cell irradiation, a time of rest of about two hours being required to achieve the 'first-irradiation' response. The fatigue effect does not occur in the steady state values to photovoltage and photocurrent. There is some evidence for a qualitative relationship between x-ray and optical photovoltage sensitivities of a cell, but there is no relationship between the photocurrent sensitivities.

Experimental determination of the wall effect for spheres falling axially in cylindrical vessels. By V. Fidleris and R. L. Whitmore.
Experimental data of the drag exerted by the walls of a cylindrical vessel on a sphere falling axially down it through a liquid are given for Reynolds numbers, based on the diameter of the sphere, between 0·05 and 20000. Existing wall-correction formulae are examined in the light of the new data, the conclusion being that the Francis and Munroe equations are the most reliable in the laminar- and turbulent-flow regions respectively. Graphs show the correction to be applied in the intermediate-flow region.

CONFERENCE REPORT

London symposium on electrical contacts. By M. R. Hopkins.
A symposium on electrical contacts was held by The Institute of Physics and The Physical Society, in collaboration with The Institute of Electrical Engineers on April 5, 6 and 7, 1961, at the Brunel College of Technology. The scope of the discussion was such as to be of interest to physicists, electrical engineers, metallurgists and chemists from industry and industrial research establishments, from research associations and from universities.

The opening session consisted of an address by Professor F. Llewellyn Jones on 'The physics of electrical contact phenomena', in which he surveyed the various aspects of contact operation, the important problems still outstanding and the methods by which they are now being attacked. The sessions which followed were devoted to 'Principles', 'Fundamental investigations and techniques', 'Contact surfaces', 'Materials and design', 'Non-metallic contacts' and 'Miscellaneous subjects'. At each of these sessions, four or five short papers were presented and followed by discussion.

INVITED ARTICLE

The physics of electrical contact phenomena. By F. Llewellyn-Jones.
An outline is given of the nature of the fundamental physics processes occurring at an electrical contact and the problems to which they give rise, particularly in relation to light duty electrical contacts. The discussion includes contacts in which currents and potentials are of the order of amperes and volts, and also the so-called electronic contacts, in which one or other or both of these quantities may be extremely small. Recent work on microscopic molten metal bridges, micro-arcs (both of which are important in metal transfer) and the problems of 'electrostatic' contacts which mainly depend on surface properties, are described. Outstanding problems are discussed and the methods by which they are being attacked are indicated.

Measurement of metal transfer in electrical contacts by the radioactive isotope method. By F. Llewellyn Jones, M. R. Hopkins and C. R. Jones.
The use of radioactive isotopes in the measurement of the transfer of metal from one electrode of an electrical contact to the other is described and details of the experimental procedure are given. The relation between matter transfer and circuit inductance at very low values of the inductance has been determined for platinum and palladium contacts operating at potential differences of the order of one volt. It is shown that for these metals there is no range of inductance down to 10^{-8}H over which the transfer is independent of inductance. The amount of transfer in relation to the volume of the molten metal bridge between the electrodes is considered, and the significance of the results in the light of theories of the phenomenon of transfer is discussed.

Experimental estimation of the degree of the ionic thermal dissociation of the CuI vapour in the air atmosphere between 350°c and 550°c. By J. Mazur and J. Rafalowicz.
On the basis of measurements of the ionic current density in the CuI vapour the ionic pressure has been evaluated as a function of temperature and afterwards compared with data given in the literature, concerning the total pressure of the CuI vapour.
Thus it was possible to calculate the thermal ionic dissociation of the CuI vapour as a function of temperature and to plot the result on a graph

Investigation of the electrical contact properties of granular carbon aggregates. By E. D. Macklen.
The heat treatment of granular carbon aggregates in various ambient gases has been studied. In inert gases (hydrogen, nitrogen, argon, etc.) and *in vacuo*, either a constant or a decreasing electrical resistance was observed for increasing heat treatment temperature. Ambient gases containing either free or combined oxygen produced a sharp resistance maximum at about 350°c. This increase in resistance is attributed to the formation of a non-conducting surface oxide layer which decomposes on increasing the heat treatment temperature.

CONFERENCE REPORT

Summarized proceedings of a symposium on electronic devices at helium temperatures. London, November 1960. By D. H. Parkinson.
A one-day symposium on electronic devices which work at helium temperatures was held jointly by the Low Temperature Group and the Electronics Group of The Institute of Physics and The Physical Society on November 15th, 1960. The emphasis was on devices which could be used in electronic computers. Recently there have been considerable advances in the research on Crowe cells and cryotrons. Both devices can be switched at high speed (~ 10 to 15 ns.) and the factors governing their performance are fairly well understood. There have been equal advances in the development of a helium refrigerator of great reliability and efficiency. With cryotrons, the conditions for reproducibility are far less stringent than with the Crowe cell and, as four terminal devices, with current gain, they offer great flexibility to computer designers, being capable of use both in the store and in logical components. The p–n junction, tunnel diode, and cryosar are also based on semiconductors and all work at helium temperatures. They could be very useful ancillary devices in computers based on superconductors, or on the other hand, computers could be based on these devices entirely and the use of liquid helium is then unnecessary. However, taking into account the low heat dissipation and close packing feasible with superconductive devices (10^9 bits in a 35cm cube), where fast computing is concerned the cryotron offers great advantages. It is moreover a device of universal application throughout a computer which may demand a new approach to logical design and the layout of the machine.

Oscillating disk viscometer. By R. Roscoe.
All the theoretical formulae proposed for the calculation of viscosity from observations made with O. E. Meyer's viscometer are seriously in error, chiefly because the disturbance of the fluid has not been treated correctly at points near to the edge of the disk. The remarkable discrepancies between results for the same fluids obtained by different observers are not, however, entirely due to formulae errors. A theoretical treatment is given here of the oscillations of a disk which is far removed from all boundaries. A proper evaluation of the edge correction is made in the two extreme cases when the penetration depth of the disturbance in the fluid is much greater and much less than the disk thickness, and the practical use of the resulting formulae is discussed. A series of measurements on the viscosity of water shows that the viscometer can give absolute results with an accuracy much better than one per cent provided a number of precautions are taken in the design of the apparatus and in the performance of the observations.

Dielectric properties of ammonium dihydrogen phosphate at very high frequencies. By E. Rushton.
Ammonium dihydrogen phosphate shows no detectable dielectric dispersion between 10 kc/s and 36 Gc/s. Determinations of the permittivity ε at a frequency of 36 Gc/s are described: the values obtained are $\varepsilon_{\parallel} = 14{\cdot}0$ at 21°c and $\varepsilon_{\perp} = 57{\cdot}1$ at 21·5°c, where $\varepsilon_{\parallel}$ and $\varepsilon_{\perp}$ are the values of permittivity when the applied electric field is parallel with or perpendicular to the optical axis. These values are not measurably different from those obtained at lower frequencies by the author (at 1 Mc/s) and by other workers (at 10 kc/s).

INVITED ARTICLE

Recent developments in high speed super-conductive devices. By D. R. Young.
The factors contolling the speed of useful cryotron circuits are: circuit geometry, insulation thickness, resistivity of superconducting film in normal state, superconducting and transition properties of films used. These factors are discussed in detail and in addition new circuit techniques are described that increase the speed of operation to the millimicrosecond range. A new type of cryotron is mentioned that introduces a significantly larger resistance in the normal state. This device is particularly useful for driving long lines such as encountered in cryogenic memory planes.

Journal of Scientific Instruments

Phase and modulation fluorometer. By J. B. Birks and D. J. Dyson.
The instrument, which is designed for the measurement of fluorescence decay times of $10^{-7} - 10^{-4}$ s, comprises a 10 Mc/s hydrogen discharge lamp, fast photo-multiplier, variable delay line and detector circuit for phase and modulation analysis of light signals from the lamp and specimen. Studies have been made of the transit time variations in 56 AVP and 6810 A photomultipliers, and preliminary measurements have been made of the fluorescence decay time of quinine sulphate solutions.

Emission control for the omegatron type mass spectrometer. By G. R. Giedd and G. C. Roberts.
The basic circuit usually used with the omegatron provides no method of regulating filament emission to maintain constant target or beam current. In operation, the basic circuit permits emission current variations of as much as ±40%, together with long term electrometer zero drift of ±15%, at an input impedance of 10^{12} ohms. A circuit of the type used for emission regulation of ion gauges is modified to provide closed loop feedback control of omegatron filament emission. Use of this circuit, which monitors and controls the target current, results in emission control of ±3% and reduces long term electrometer zero drift to ±5%.

Measurement of magnetic field contours. By R. Freeman.
A simple apparatus is described which can be used to plot the field contours of a laboratory magnet, even when the instability of the field in time is comparable with the variations in space. It consists of two super-regenerative oscillators which produce signals at the nuclear magnetic resonance frequencies of the proton samples in their tank coils. One sample is fixed while the second scans the magnetic field, and the field difference between the two probes is presented in frequency units on an electronic counter. The method can be extended to make the field mapping operation completely automatic.

Automatic method of magnetic field calibration using proton resonance. By A. Horsfield, J. R. Morton and D. G. Ross.
A circuit is described which enables the automatic calibration of a magnetic field to be carried out. A marginal oscillator, frequency controlled by one of eleven quartz crystals mounted in a motorized turret tuner, detects nuclear magnetic resonance signals. These signals activate a pen recorder and also trigger a control circuit which advances the turret tuner to the next channel.

Method of linearizing thermistor thermometer data in calorimetry. By H. V. Larson, L. T. Myers and W. H. Le Blanc.
A method of correcting for the non linearity of thermistor thermometers in calorimetry is described. The correction may either be expeximentally determined, or calculated from the thermistor specifications. This system of reducing thermistor data was applied to measurements over temperature differences of several degrees in two different adiabatic calorimeters. A linear temperature resolution of 10^4 to 1 was easily obtainable.

Instrument for the continuous determination of the mechanical internal energy losses in high polymer solids, over a wide range of temperature and frequency. By P. Lord and R. E. Welton.
An instrument has been developed for the continuous measurement of the dynamic modulus and the mechanical loss factor of high polymer solids, over the frequency range 0·5 c/s to 2 kc/s, and at temperatures between −100°c and +140°c. The phase and amplitude of torsional oscillation of an electromagnetically driven specimen are measured with the aid of a capacitance transducer. The temperature is controlled by an adiabatic vaccuum system.

Aperturometer for microscope objectives. By C. J. D. Spencer and W. T. Welford.
In conventional apertometers accuracy is limited by parallax between the effective aperture stop and the scale image. This is overcome by the use of a projection system in the device described.

Proceedings of The Physical Society

On the extra reflections in electron diffraction patterns from thin evaporated films of some of the face-centred cubic metals. By Kanwar Bahadur and P. V. Sastry.
Polycrystalline thin films of a number of face-centred cubic metals have been prepared by evaporation on to rock-salt, followed by annealing. In a number of cases, transmission electron diffraction patterns show, in addition to the normal face-centred cubic rings, some extra rings which fit well with those which would be expected from a hexagonal close-packed form of the metals. No hexagonal close-packed rings are observed with aluminium films, and this is correlated with the absence of stacking faults on transmission electron microscope images of aluminium films.

An analogue solution of the continuity equation of the ionospheric F region. By B. H. Briggs and H. Rishbeth.
It is shown that the continuity equation for the electron density in the F region of the ionosphere can be solved by the use of an electrical analogue. The equation which is solved in this way takes account of the rates of production and loss of electrons, and of vertical diffusion, but other types of movement are not included. The rates of production, loss and diffusion are assumed to vary with height in a manner appropriate to a particular model of the atmosphere, based on rocket and satellite data.
The analogue computer is first used to find how the electron density at a series of heights varies with time due to the diurnally varying rate of production. The time of maximum production is at noon, but the time of maximum electron density occurs some time after noon, and the variation of this time lag with height is studied. Near noon, the electron density is found to be a maximum at a height of 250 km. In the evening, the height of maximum rises to about 300 km, and remains constant during the night. Above the level of the maximum, the ionization is controlled by diffusion and the ionization density falls off exponentially, with increasing height; its time variation follows closely the time variation at the maximum.
In other experiments, the production function is modified so as to represent a solar eclipse which occurs near noon. Diurnal curves of electron density are obtained at a series of heights, and the results show how the time of maximum electron density and the percentage decrease of electron density vary with height.
In another type of experiment, the diffusion and recombination of a slab of ionization introduced at a fixed height are studied. It is shown that the slab spreads out to form a 'layer' which eventually assumes a certain fixed shape with a maximum at a fixed height of 300 km, and that this 'shape-preserving' layer then decays with a time-constant determined by the rate of recombination at the level of maximum ionization density. The final form of the layer is independent of the height at which the slab of ionization is introduced. These results may be relevant to the behaviour of the F layer at night when production is absent, and diffusion and recombination are the controlling factors.

γ-ray spectra in large organic scintillators. By P. R. J. Burch.
For moderately large organic scintillators, it is found between the position of the γ-ray 'Compton peak' and the maximum energy transfer in a first Compton collision. Extrapolation yields a positive intercept on the energy axis as a result of the dependence of the specific light output of scintillators on the linear energy transfer of charged particles. The broadening of the Compton peak on the high-energy side has three components: (*a*) statistical, (*b*) intrinsic line broadening arising from multiple interactions of the γ-ray, and (*c*) geometrical—resulting from the variation of light collection efficiency with the position of the event in the scintillator. The dependence of these three components on γ-ray energy is considered and their approximate magnitudes for two plastic scintillator units are calculated from experimental γ-ray spectra.

Gamma radiation from the medium energy proton bombardment of lithium, beryllium, boron, carbon and nitrogen. By A. B. Clegg, K. J. Foley, G. L. Salmon and R. E. Segel.
Measurements are presented of the gamma radiation produced when lithium, beryllium, boron, carbon and nitrogen are bombarded with 150 mev protons, and the results are discussed with reference to the information they provide about the structure of the nuclei involved. The results include measurements of the residual states produced in (p,2p) and (p,pn) reactions, which are, to a first approximation, measurements of the parentage of the ground state of the bombarded nucleus. These results are not consistent with a simple *jj*-coupling model of these nuclei and, in one case where calculations are available, are consistent with an intermediate coupling model. It is shown that inelastic scattering cross sections are determined by the same matrix element as radiative transitions so that inelastic scattering is a powerful tool for picking out strong radiative transitions to nuclear ground states.

Electrical breakdown of gases: ionization growth in air at high pressures. By J. Dutton, F. Llewellyn-Jones and R. W. Palmer.
The experimental conditions which have to be satisfied in order to measure ionization coefficients accurately at high values of the parameter pd (pressure × gap distance) are discussed. In an apparatus designed to fulfil these conditions, precision measurements were carried out for uniform electric fields E in air at values of the parameter pd up to 2300 mm Hg cm, which corresponds to a sparking potential of about 80kv, thus extending the range so far investigated by Llewellyn-Jones and Parker in 1950 and 1952. The results show that pre-breakdown ionization growth in air is due to the action of primary (α) and secondary (α_s) ionization processes, modified by the process of attachment (a), and that significant space charge effects were absent. At a value of pd of 2300 mm Hg cm the sparking potential calculated (81 ± 1·5kv) from the criterion (expressed in terms of the ionization and attachment coefficients) which gives the static sparking potential was in agreement, within the experimental error, with that (79 ± 0·7kv) observed. It is also shown that the state of the cathode surface had a marked influence on the secondary ionization even at these higher values of pd.
For $35 \leqslant E/p \leqslant 40$v cm^{-1}/mm Hg)$^{-1}$ and pressures between 400 and 1000 mm Hg, the apparent secondary ionization coefficient $\alpha/(\alpha - a)$ was found to be a function of E/p alone, whereas the apparent primary ionization coefficient $(\alpha - a)/p$ showed a small, just detectable decrease with increasing pressure at a given value of E/p.

Coherent and incoherent scattering of x-rays by H_2 and He. By G. E. Kilby.
An electron density map calculated by Rollett from an accurate function of James and Coolidge has been used to obtain the coherent x-ray scattering from molecular hydrogen. The results given by the Coulson self-consistent field function are also presented, and it is shown that there is excellent agreement with the James–Coolidge results and with earlier calculations of Carter, March and Vincent.
In addition a more careful study of the incoherent scattering has been made than has previously been attempted. By considering two correlated wave functions, that of Shull and Löwdin for helium and that of Gurnee and Magee for hydrogen, previous approximations are shown to lead to somewhat high estimates of the total scattered intensity. For hydrogen, a maximum reduction of about 4% brings theoretical results to within 1% of the experimental values of Wollan.
The momentum distribution and the corresponding shapes of the Compton lines have also been considered for hydrogen and helium. It is suggested from the results obtained for molecular hydrogen that more accurate measurements of the Compton profile might afford a useful method of studying bonding electrons.

Extension of series in the first spectrum of indium (In I). By W. R. S. Garton and K. Codling.
The ultra-violet absorption spectrum of indium vapour has been photographed by means of a 3 metre grating spectrograph. Lines of the series $5^2P_{1/2}$–$n^2S_{1/2}$ (n=9 to 27), $n^2D_{3/2}$ (n=7 to 33), $5^2P_{3/2}$–$n^2S_{1/2}$ (n=10 to 29), $n^2D_{5/2}$ (n=8 to 19), $n^2D_{3/2}$ (n=8 to 34), have been measured against good wavelength standards. A short sixth series is identified as $5^2P_{1/2}$–$n^2P_{1/2}$. The accepted value for the ionization potential has been confirmed. From a consideration of the character of the perturbation in the n^2D series we conclude that the sp^1 ^1D term lies above the ionization limit instead of, as formerly supposed, below.

Twinning in a cation-deficient spinel structure. By J. Goodyear and G. A. Steigmann.

Crystals of β-In_2S_3 have been studied under the polarizing microscope and by x-ray diffraction. Optical examination has shown that the crystals are twinned, and the relative orientations of the twin components have been determined by rotation and oscillation x-ray photographs. The diffraction data has also confirmed the body-centred tetragonal cell proposed by Rooymans. Assuming that the material has a spinel structure, deficient in cations, it follows that twinning takes place when a redistribution in the tetrahedrally occupied sites occurs.

The energy levels of the magnesium isotopes of mass 25 to 28. By S. Hinds, H. Marchant and R. Middleton.

The energy levels of the magnesium isotopes of mass 25 to 28 inclusive have been measured with a broad-range magnetic spectrograph using a variety of deuteron and triton induced nuclear reactions. The following is a list of the reactions used to study each magnesium isotope together with the number of levels observed below a particular excitation energy:

^{25}Mg	^{24}Mg (d, p) ^{25}Mg	54 levels below	7·64 mev
	^{27}Al (d, α) ^{25}Mg	54 levels below	7·64 mev
^{26}Mg	^{25}Mg (d, p) ^{26}Mg	49 levels below	8·617 mev
	^{24}Mg (t, p) ^{26}Mg	63 levels below	9·370 mev
	^{27}Al (t, α) ^{26}Mg	87 levels below	10·515 mev
^{27}Mg	^{26}Mg (d, p) ^{27}Mg	18 levels below	5·017 mev
	^{25}Mg (t, p) ^{27}Mg	42 levels below	7·031 mev
^{28}Mg	^{26}Mg (t, p) ^{28}Mg	19 levels below	6·759 mev

The Manchester high energy magnetic cosmic ray spectrograph. By J. E. R. Holmes, B. G. Owen and A. L. Rodgers.

Modifications to the Manchester counter spectrograph are described which have permitted the momentum measurement of single cosmic ray particles to a maximum detectable momentum of 1000 oev/c. The measured output of the instrument was 20 particles per day of which approximately 50% had momentum exceeding 10 oev/c and 2% exceeding 100 oev/c.

Measurements of the momentum spectrum and charge ratio of cosmic ray muons at sea level in the momentum range 10 oev/c–1000 oev/c. By J. E. R. Holmes, B. G. Owen and A. L. Rodgers.

The momentum spectrum of single cosmic ray muons arriving at sea-level in the N.S. plane at 57°N geomagnetic latitude has been measured for near vertical incidence. Results are given which cover the momentum range 5 oev/c $< p <$ 1000 oev/c, and together with the earlier work of Owen and Wilson form a continuous spectrum from 0·5 oev/c to 1000 oev/c. The high momentum work is based on 1800 particles of momentum greater than 10 oev/c.

The charge ratio of single muons arriving at sea-level has been measured, for near vertical incidence, to an upper momentum limit of 100 oev/c. The measurements are compared with those of other workers and together show evidence for a maximum in the sea-level charge ratio in the momentum range 3 oev/c to 7 oev/c.

The Michelson stellar interferometer: a phase sensitive variation of the optical instrument. By R. C. Jennison.

A short summary is given of a variation of the Michelson stellar interferometer. This is an adaptation of part of the principle of the radio frequency phase-sensitive interferometer developed by the author, and it enables the phase component associated with the structure of the source to be determined. The technique may also be used to determine the correct relative amplitude of the visibility function of the star at two spacings even when phase and amplitude errors are present.

Absorption spectrum of BiF molecule in the ultra-violet region. By K. C. Joshi.

One system of bands comprising thirty-two bands of the BiF molecule has been obtained in absorption in the region $\lambda\lambda$2400 – 2180. Three of these bands were previously observed in emission by Rochester. The bands have been analysed and can be represented by the following formula:

$$\nu_{v'v''} = 44222{\cdot}0 + 615{\cdot}0\,(v' + \tfrac{1}{2}) - 2{\cdot}50\,(v' + \tfrac{1}{2})^2 - 312{\cdot}0\,(v'' + \tfrac{1}{2}) + 2{\cdot}25\,(v'' + \tfrac{1}{2})^2.$$

A discussion regarding the electronic states involved in the transition shows that the ground state is a triplet state, whereas the upper one is a single state and not otherwise as suggested by Rochester.

The magnetoelastic constants of nickel. By E. W. Lee and R. R. Birss.

The magnetoelastic constants of nickel are calculated from the magnetostriction constant measured by Birss and Lee in 1960 and elastic constants measured by Alers, Neighbours and Sato in 1960. It is shown that the temperature variation of these magnetoelastic constants is in good agreement with the theory proposed by Kittel and Van Vleck in 1960. According to this theory the magnetoelastic constants depend upon the magnitude of the spontaneous magnetization. This may be increased slightly by a large magnetic field and it is shown that the theory explains, in principle, the origin of the forced magnetostriction.

Electron spin resonance studies of impurity ions in magnesium oxide. By J. W. Orton, P. Auzins, J. H. E. Griffiths and J. E. Wertz.

The univalent ions Fe^{1+}, Co^{1+} and Ni^{1+} have been produced by ultraviolet or x-irradiation of impure MgO crystals. The electron spin resonance spectra of these ions are compared with those of the isoelectronic ions Co^{2+}, Ni^{3+} and Cu^{2+} which they resemble closely. The spectra of Fe^{1+}, Co^{1+} and Ni^{1+} show line-width effects which may be interpreted as being due to the presence of small distortions in the cubic crystal lattice. A detailed report of the $3d^9$ configuration in a cubic field is given. There is a transition at low temperature from an isotropic to an anisotropic spectrum, presumably due to the ' freezing in ' of Jahn-Teller distortions. Observation of hyperfine structure from ^{61}Ni has made it possible to estimate the nuclear moment by comparison with the observed hyperfine structure from Cu^{1+}. The case of formation and stability of these univalent ions is shown to be related to the concentration of positive ion vacancies and to the concentration of trapped hole centres.

Low temperature electric field effects in semiconductors. By V. V. Paranjape.

Germanium shows at liquid helium temperature a very strong rise in conductivity with field strength at about 2v cm^{-1}. This process has been investigated theoretically on the basis of electron temperature concept. The variation of the density of electrons with field is calculated considering excitation of donors into the conduction band by impact ionization and phonon absorption as well as reverse processes. It is shown that the current, though strongly field dependent, is always stable and an expression for current density as an explicit function of the field strength is obtained. Good agreement with experiments supports the validity of this theory.

The electronic structure and spectrum of nitrobenzene. By T. E. Peacock.

The self-consistent field molecular orbital theory has been used to calculate the π electronic structure and spectrum of nitrobenzene.

Measurements of rotational temperature in ionic collisions. By E. M. Reeves and R. W. Nicholls.

The measured rotational intensity distribution of N_2^+ first negative bands excited by 1 mev protons indicates that the rotation of the molecules is not greatly affected by the collisions. Measured rotational temperatures compare favourably with the laboratory temperatures. Similar observations on N_2^+ bands excited by 1 to 3 kev Li^+ ions show that these collisions appear to cause a much greater departure from Boltzmann distribution of rotational energies. Energy levels of low and of high quantum numbers are enhanced in population.

H_2^+: A problem in perturbation theory. By P. D. Robinson.

A résumé is given of how accurately perturbation theory (using a ground-state hydrogen-like atom perturbed by a point charge) predicts the 1sσ and 2pσ energies of H_2^+ and HeH^{++}. The corresponding delta-function models are discussed ; here it is possible to test the convergence of the perturbation expansions. The models indicate that the series for the 1sσ energy is divergent for H_2^+ at large values of the internuclear separation, R, but convergent for HeH^{++}; this explains why the H_2^+ series is inaccurate and the HeH^{++} series is accurate. Both series converge for small R. The 2pσ energies are represented by divergent series which are asymptotically convergent if R is sufficiently large. A ' resonance ' correction is justified for the H_2^+ series, giving an accurate 1sσ energy for all R and an improved 2pσ energy.

Knock-on electrons and direct electron pair production by cosmic-ray muons. By P. H. Stoker, C. Holmeyr and H. Bornman.

Knock-on electrons and direct electron pair creation by cosmic-ray muons in thin lead plates were investigated with a multiplate cloud chamber. The muons traversing the cloud chamber were classified into two energy intervals, viz. 450 to 1700 mev and higher than 1700 mev. By comparing the experimental results with theoretical predictions which were derived for the knock-on process, an effective range–energy relationship was found for electrons in lead with energies up to about 200 mev. The experimental distributions of the knock-on production as a function of the energy transfer compare well with theoretical distribution calculated from Bhabha's formula for muons in both of these energy ranges. The comparison between the theoretical and experimental results is also satisfactory for the energy distribution for direct pair production by muons with energy above 1700 mev. The theoretical distribution was calculated from a formula deduced anew from the differential cross section given by Murota *et al.* The experimental results favour a value between 1 and 2 for the indefinite constant α of the theory.

Electrical breakdown of liquid dielectrics. By D. W. Swan.

Assuming that electron emission from the cathode and collision ionization in the liquid are both necessary for the electrical breakdown of liquid dielectrics, a criterion for breakdown is developed in which the cumulative effects of the applied field and the space charge field of the positive ions produce a continuously increasing electron current at the cathode. The present theory differs from earlier similar theories in that the ionization occurring in the liquid is considered to be very small even at breakdown, in agreement with recent conduction measurements. The breakdown criterion shows clearly how the measured electric strength can depend on either the cathode or the liquid. The influence on the breakdown measurements of dissolved oxygen is also discussed, and the quantitative predictions of the theory are compared with measurements of the electric strength of liquid argon.

The influence of cathode and anode surfaces on the electric strength of liquid argon. By D. W. Swan and T. J. Lewis.

The electric strength of liquefied argon is found to depend to a marked degree on the nature of both cathode and anode. This effect has been investigated systematically. The cathode is thought to influence the strength through the process of electron emission into the liquid, whilst the anode becomes important only if the rate of emission from the cathode exceeds that at which the anode can accept charge. In this case a high space charge field is set up near the anode which can lower the applied field necessary for breakdown. By measuring the electric strength of liquid argon containing various concentrations of oxygen, it has been shown that probably the anode space charge is formed only when part of the current before breakdown is carried by negative oxygen ions. The electric strength is found to be very sensitive to small concentrations of oxygen.

LETTERS TO THE EDITOR

The determination of the half-life of RaC'. By T. Dobrowolski and J. Young.

New heavy bosons. By H. Fröhlich.

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CONTRACT EMPLOYMENT: If desired by the successful applicant consideration may be given to entering into an agreement for a three (3) or five (5) year contract of employment in Australia. In this case the Commonwealth will bear the cost of return fares; together with the cost of removing the successful applicant's furniture and effects up to a maximum cost of £500 (Australian), £250 each way.

APPLICATIONS: Forms obtainable from Senior Representative (AV.108/6), Department of Supply, Australia House, Strand, London, W.C.2., with whom completed applications should be lodged as soon as possible.

PRINTED ELECTRONIC CIRCUITS

A RESEARCH ASSISTANT is required to work on new types of printed electronic circuits. Experience in related fields, and in particular photographic techniques, etc., would be desirable. The post carries an attractive salary; pleasant working conditions in a well-equipped laboratory; five day week. Evening or week-end interviews can be arranged if desired. Please apply Personnel Manager, G. V. Planer Ltd., Windmill Road, Sunbury-on-Thames, Middlesex. (Sunbury 2266).

UNIVERSITY OF NATAL
DEPARTMENT OF MATHEMATICS AND APPLIED MATHEMATICS

Applications are invited from suitably qualified persons for appointment to the post of SENIOR LECTURER IN MATHEMATICS OR APPLIED MATHEMATICS, Durban. A background in Statistics is desirable but not a necessity. The salary scale attached to the post is R3,180 × 120–R4,140 (£1,590 × £60–£2,070) per annum. Application forms and further particulars of the post, including commencing dates, etc., are obtainable from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1. Applications close, in South Africa and London on June 20, 1961, or as soon as possible thereafter.

AUSTRALIA
THE UNIVERSITY OF NEW SOUTH WALES
STAFF APPOINTMENTS—SCHOOL OF PHYSICS

The University of New South Wales wishes to appoint academic staff to the School of Physics. The School offers courses to students taking physics at the B.Sc., and honours levels, and also to those undertaking research work for the degree of M.Sc. and Ph.D. in the Faculty of Science. Physics is also taught to first and second year students in other Faculties. The School is active in research, particularly in the fields of solar-furnace high-temperature studies, N.M.R., acoustics, and gas-discharge physics, and in aspects of solid-state physics, including X-ray crystallography, dielectric breakdown, low-energy electron diffraction, and vacuum-ultraviolet studies of surfaces. Facilities for research work of staff and postgraduate students are good. There are well-equipped mechanical, electrical, and optical workshops, and the University has a large electronic digital computer (UTECOM, an English Electric DEUCE machine). Enquiries about the School of Physics may be addressed to the Head of the School, Professor C. J. Milner. For appointment as SENIOR LECTURER applicants must have a higher degree or equivalent qualifications. Applicants for the position of LECTURER must have a degree with honours in physics. Salary: Senior Lecturer: £A2,592 range £A3,042 per annum. Lecturer: £A1,772 range £A2,477 per annum. Commencing salaries for these positions are determined by qualifications and experience. Successful applicants will be eligible, subject to passing a medical examination, to contribute to the State Superannuation Fund. First class ship fares to Sydney of appointees and their families will be paid. Four copies of applications (including the names of two referees) should be lodged with the Agent General for New South Wales, 56-57 Strand, London, W.C.2, and a copy forwarded to the Appointments Section, The University of New South Wales, Box 1, Post Office, Kensington N.S.W., Australia, by airmail to arrive before July 14, 1961. Applicants outside the United Kingdom and Eire need only submit one copy of their application to the London address in addition to the copy sent to Sydney.

ROYAL MILITARY COLLEGE OF SCIENCE, SHRIVENHAM, BERKSHIRE require SENIOR LECTURERS or LECTURERS in PHYSICS, MATHEMATICS AND ELECTRICAL ENGINEERING. Teaching at University level. To lecture to degree courses (and possibly specialized courses) and assist with laboratory classes. There are extensive well-equipped laboratories. Research encouraged and work would be suitable for publication and submission for higher degree. Qualifications: 1st or 2nd class Honours degree or equivalent, preferably with teaching and/or research experience.

THE INSTITUTE OF PHYSICS
AND
THE PHYSICAL SOCIETY
EDITORIAL DEPARTMENT

Two assistants are required in the Institute and Society's Editorial Department at Lowther Gardens.

(*a*) Senior Assistant with Physics and/or Mathematics to degree standard and some secretarial experience. Work will include preparation of material for publication, correspondence in connection with publications, a small amount of committee work and responsibility for the day to day running of the office. Salary £750 – £800 according to qualifications and experience.

(*b*) Editorial Assistant with Physics and/or Mathematics to degree standard to assist in preparation of material for publication. Ability to type an advantage. Salary £650 – £700 according to qualifications and experience.

For both posts meticulous accuracy is essential and some experience in editorial work or knowledge of scientific instruments would be an advantage.

Further details and application forms from the Editor and Deputy Secretary, The Institute of Physics and The Physical Society, 1 Lowther Gardens, Prince Consort Road, London, S.W.7.

PHYSICIST expected to engage in research in nuclear physics, radiation physics or solid state physics. MATHEMATICIAN should preferably have interest in applied mathematics. ELECTRICAL ENGINEER to have thorough grounding in electrical engineering, experience in electrical power and machines and/or electrical theory and measurements. Salary range: Senior Lecturer—£1,302 to £1,604; Lecturer —£717–£1,186.
Starting pay may be above minimum in both cases; credit for postgraduate experience and National Service. Superannuation under F.S.S.U. Good prospects of permanency. Residential accommodation for single staff, houses for married staff. Further particulars and forms from Registrar, R.M.C.S., Shrivenham, Berks, quoting reference H.Q.77/17.

UNIVERSITY COLLEGE OF SOUTH WALES AND MONMOUTHSHIRE

Applications are invited for a RESEARCH ASSOCIATE to perform theoretical work on semiconductors, as a member of a small group in the department of Applied Mathematics. The appointment will be for a period of three years in the first place, and will carry a salary of up to £1,000 per annum, depending on age and qualifications. Applications (including the names of two referees) should reach Professor P. T. Landsberg, Department of Applied Mathematics, University College, Cardiff, Wales, by June 20, or as soon as possible.

UNIVERSITY OF OTAGO
New Zealand
SENIOR LECTURER OR LECTURER IN PHYSICS

Applications are invited for this position. It is hoped to make the appointment at the Lecturer level (salary £1,250 × £75 – £1,700 per annum) but an appointment would be possible at the Senior Lecturer level (salary £1,750 – £2,000 per annum) if a suitably qualified applicant was available. Further particulars are available from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1, or from the Registrar, University of Otago, Dunedin, New Zealand. Applications close, in New Zealand and London, on July 15, 1961.

ELECTRONIC SPECIALIST required by University College, London (Gower St., W.C.1) for work on development of equipment for automatic measurement of bubble chamber films and nuclear emulsion. Experience in either servomechanisms or digital circuits. Salary range £935-£1,060. Four weeks holiday. Applications to Secretary, quoting Physics/5.

QUEEN MARY COLLEGE
(UNIVERSITY OF LONDON)

Applications are invited for a RESEARCH FELLOWSHIP IN NUCLEAR PHYSICS GROUP of the DEPARTMENT OF PHYSICS. To prepare and participate in experiments on the 7 GeV proton synchrotron at the Rutherford High Energy Laboratory of the National Institute for Research in Nuclear Science. Period of appointment from October 1, 1961, for two years with possibility of renewal for a further year. Salary: £900 × £50 with F.S.S.U. Application forms, obtainable from the Registrar, Queen Mary College, Mile End Road, E.1, to be returned by June 29.

THE LATYMER SCHOOL
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WOOLWICH POLYTECHNIC,
LONDON, S.E.18

PRINCIPAL: HAROLD HEYWOOD, D.SC., PH.D., A.C.G.I., WH.SCH., M.I.MECH.E., M.I.CHEM.E.

Applications are invited for the following appointments in the Physics Department: LECTURER WITH AN HONOURS DEGREE. A knowledge of either X-ray Crystallography or of Nuclear Physics would be an advantage, but is not essential. There are facilities for research. ASSISTANT LECTURER, GRADE B, to teach in the first instance, up to General Certificate of Education, "A" level and Part I B.Sc. General Degree. The Physics Department is a large one with courses for the B.Sc. General degree and B.Sc. Special degree in Physics (Internal) of the University of London. Salary: Lecturer £1,370 × £35 – £1,550, Grade B within £828 – £1,426, according to qualifications and experience, both posts plus London Allowance £38 – £51. Particulars and application form from Clerk to Governors, to be returned by June 30, 1961.

COURSES

BATTERSEA COLLEGE OF
TECHNOLOGY
LONDON, S.W.11
PHYSICS DEPARTMENT
(i) POSTGRADUATE COURSES

The following postgraduate courses will be held during the session 1961-62. Autumn Term begins October 2, 1961. 1. Microwave Physics (full-time or part-time) leading to the M.Sc. or the Postgraduate Diploma of the College. 2. Principles and Practice of Radiation Protection (full-time or part-time) leading to the Postgraduate Diploma of the College. 3. Radiological Protection (evening course) leading to the Certificate of the College. The Department of Scientific and Industrial Research has accepted the full-time courses in Microwave Physics and in Principles and Practice of Radiation Protection as suitable for tenure of its Advanced Course Studentships. The two courses on radiation protection are in accordance with the recommendations of the Veale Committee Report on "Training in Radiological Health and Safety". Full details and enrolment forms from the Secretary (Microwave Courses) or (Radiological Courses) as appropriate.

BATTERSEA COLLEGE OF TECHNOLOGY

(A COLLEGE OF ADVANCED TECHNOLOGY)

Crystallography Section

A postgraduate course leading to the examinations for the degree of M.Sc. in Crystallography of the University of London or the Postgraduate Diploma of the College (D.C.T. (Batt.)), will begin on October 2, 1961. Full-time or part-time students are accommodated, and in certain circumstances scholarships are available. For further details apply to Dr. D. Lewis, Head of the Crystallography Section, Battersea College of Technology, Battersea Park Road, London, S.W.11

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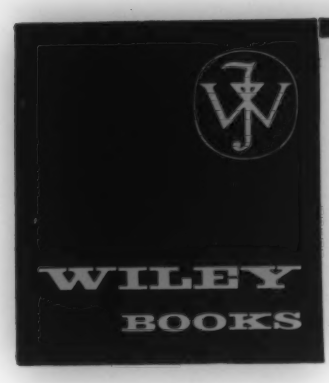

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